

never more than three sources listed in a paragraph, some paragraphs present no references, and one paragraph has one 2003 reference on redlining, for which there is now a very substantial and current literature. The Committee encourages the chapter authors to better define redlining, explicitly noting that it was based on race and poverty. The unevenness of literature employed may send a message that this key message did not get as much attention, as opposed to a lack of attention in the literature. Still, the message is clear and quite powerful overall, but the Committee suggests including additional references to adequately support the text.

On the other hand, the authors miss the opportunity to weave in concerns about mitigation. For example, literature about how these inequities drive advocacy for mitigation could be included. The discussion includes an important message on managed retreat that should cross-reference Chapter 22 (Southeast) at the very least, and harmful terminology should be avoided and made consistent with other chapters. About one page is devoted to adaptation and it is well done, with valuable information on tribal efforts.

Key Message 21.4. Climate Action Plans Are Now Being Implemented. The discussion of this key message includes a four-page table, which summarizes recent planning and action by states and tribes. It is a long list of laws with no context or indication of their content. Such a database, lacking analysis or expanded explanation, may be more useful to cite rather than reproduce in this document. The discussion also includes two boxes. The first box is on innovative municipal actions (Portland, Pittsburgh, Morgantown). The second box presents examples of adaptation efforts lead by Tribal Nations (WAMPUM, Shinnecock, MI'kmaq). Although both boxes are consistent with the guidance provided in Chapter 2 of this report, they read like instructional manuals rather than a review of literature. The key message overall relies too much on the boxes for factual demonstration.

The Committee appreciates the box on municipal adaptation and suggests at least brief acknowledgment of the extensive municipal level planning for climate change under way in cities like Boston, New York, Philadelphia, and Baltimore, among many others. Perhaps municipal-level adaptation to coastal risks was covered in prior NCAs, but some brief discussion would be welcome, and could easily be done by consolidating the analysis of state-level action.

One mention of RGGI is a criticism of issues of social inequity implicit in such systems. This is an important issue, but the Committee encourages the chapter authors to consider the overall impression of mitigation conveyed if this is the only message about mitigation provided. The Committee also suggests that the authors consider the example of the recent passage of the New York State Environmental Bond Act as a worthy example of progress.

Key Message 21.5. The Implementation of Climate Plans Depends on Adequate Financing. In keeping with other key messages in this chapter, mitigation is given short shrift. Mitigation is mentioned in the text of the key message, but the discussion only addresses impacts and risk. Most paragraphs lack references, although some have one or two, including dated ones. The high confidence in the key message should indicate that there is significant literature on these topics. If that is true, more literature should be cited throughout the supporting text and corresponding traceable account as evidence for the ranking.

Most of the discussion of the topic is at the national level with only some of it focusing on the region. Three topics that seem relevant to this key message are not covered or not adequately covered. First, the Committee suggests the text discuss the literature about who has access to financing and funding, who benefits, and whether benefits reach the most vulnerable populations. Second, literature on access and distribution of burdens and benefits should be

represented. Finally, a mention of literature on the role of land trusts in conservation might fit in this key message.

Comments on Traceable Accounts

The traceable accounts require attention. As written, they are concise, but they do not sufficiently explain how the chapter authors arrived at a confidence assessment based on strength of evidence and agreement about process, nor do they explain the basis of the likelihood statements.

The section “Description of Evidence Base” does not cite literature. It would seem more appropriate to focus on the scientific demonstration of the basis of the key messages in the traceable accounts section and use the expanded discussion of the key messages in the body of the text as a place to explain the key messages to broad audiences and provide context and implications.

Comments on Graphics and Boxes

The figures are well done, but minor revisions, especially of the captions, are necessary to ensure that they are self-contained, even if that repeats text. Consistent with the recommendation in Chapter 2 of this report, captions should provide an explanation of the figure message and explain how to read the figure.

Figure 21.3 is mislabeled. Additionally, the Committee found Figure 21.3 challenging to interpret and difficult to read because of its fuzziness. The Committee suggests expanding the explanation of the figure in the caption and making sure that the numbers in the legends are clearly defined and described. For example, it would be helpful to explain the “relative log of biomass.”

Figure 21.4 as presented is somewhat confusing with varying numbers of images without connection to messages. The Committee suggests labeling the panels: 1985, 2015, 2050. Additionally, the right panel suggests that cod have increased by 2050 but will decline after. The middle panel suggests herring have increased by 2015 but then will decline by 2050 and after. Similar with lobster and puffin. It seems that the art in this scenario may not be connected to the science, and the Committee suggests trying to better align the two. If the figure already does align the art and science, these apparent enigmas should be clarified in the figure caption.

Comments on Equity and Justice

Overall, the chapter could benefit from some clear framing (perhaps in the introduction) on vulnerable regions and populations, as well as the structural, environmental, and social factors that contribute to vulnerability, and just transitions. Please refer to Appendix A for other specific suggestions. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Data and Analyses

The section relies on data and analyses reported in the existing literature and other sources. The chapter authors do a good job applying the data from the existing literature in a consistent, transparent, and credible manner.

Comments on Literature Cited

In general, citations refer to literature that post-dates NCA4. Exceptions are not problematic. There does seem to be an overreliance on self-reported advances, such as reports by cities of their own activities rather than objective, independent assessments from the peer-reviewed literature. The Committee suggests providing a discussion on how literature was selected in the traceable accounts.

There is duplication between the bullets on page 21-19 and table entries. Boxes 21.1 and 21.2 have the basic documentation expected. But Box 21.2 suffers from only relying on the originator of plans to describe them and lacks a sense that a meta-analysis is available or even desirable. Most content (and documentation) is restricted to the table and boxes.

Key Message 21.5 suffers more from a paucity of sourcing and has some questionable sources burdened by age or lack of peer review. For example, page 21-29, line 14, cites “USA facts 2021” as the only source for the paragraph. There is too much emphasis on accepting the word of exemplar institutions for their actions as opposed to a professional appraisal of such actions.

In general, the Committee found that significant literature relevant to the key messages of this chapter is not cited in the supporting text. Some of this literature may be cited by referencing the IPCC AR6. Examples of literature that the committee suggests (full citations are provided in the References chapter) chapter authors may consider include the following: Bhattachan et al. (2018); Booth et al. (2021); Chen et al. (2019, 2021a); Dougherty and Rasmussen (2019); Ebi et al. (2021); Ellena et al. (2020); Farr et al. (2021); Foster et al. (2019); Friedland et al. (2021); Gaichas et al. (2018); Holmquist et al. (2021); Houghton and Castillo-Salgado (2019); Huang et al. (2018, 2021); Jeanson et al. (2021); Kjesbu et al. (2022); Knighton et al. (2019); Leonard (2021); Letson et al. (2021); Lotze et al. (2022); Mayrhuber et al. (2018); McMullin et al. (2019); Molino et al. (2020); Nazarian et al. (2022); Nunfam et al. (2018); Olafsdottir et al. (2021); Overland et al. (2021); Papaioannou et al. (2021); Pershing et al. (2021); Piecuch (2018); Powell et al. (2019); Reckien and Petkova (2019); Robertson et al. (2022); Rogers et al. (2019); Rosenau et al. (2021); Runkle (2022); Schattman et al. (2021); Setzer and Vanhala (2019); Shen and Chui (2021); Sicard et al. (2018); Thomas et al. (2019); Thorne et al. (2019).

Other Recommended Changes

The introduction makes the point that the findings of NCA4 are still valid and relevant, and that the literature cited there is still useful. While this is surely mostly the case, some cautionary note is appropriate in the absence of a critical retrospective. See comments provided in Appendix A for more suggested detailed clarifications.

CHAPTER 22: SOUTHEAST

Summary

This chapter describes the patterns of risk, social vulnerability, and climate adaptation in the Southeast region. The writing throughout this chapter is inconsistent, with some sections that are clear and concise (e.g., Key Message 22.2), while others are written at a more technical level. These sections should be revised to be appropriate for broad audiences. Additionally, the findings are not particularly consistent nor are they transparent, and suggestions provided below would improve this chapter's compliance with Section 106 of the GCRA. The traceable accounts section could be revised to describe processes of the literature review and how the authors assigned confidence levels. The chapter could also list the climate changes unique to the Southeast region.

The chapter spends a great deal of space on the health of people in the region broken out by risks yet does not include the widespread use of harmful natural resource extraction practices. The chapter could also build on NCA4 to report an updated assessment of the region's infrastructure. For example, the region's lack of disaster preparedness and response infrastructure given the increased frequency of climate-related disasters could be discussed.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction of this chapter is generally well written. However, the introduction should define which states are included in the Southeast, perhaps by showing a map of the region. The introduction could also provide more discussion on specific climate changes in the region. The Southeast is a unique region that has experienced a long-term cooling over the past century under the background of global warming. This phenomenon is sometimes called the Southeast US "warming hole." Whether the cooling will continue into the coming decades or reverse remains uncertain and can potentially affect the aspects covered in the chapter. Therefore, disaster preparedness and response infrastructure will be particularly critical. It may be worthwhile mentioning this in the chapter and including a few references. Another unique aspect to the Southeast worth mentioning is its diversity in landscapes and economy.

Comments on Key Messages, Supporting Information, and Traceable Accounts

Comments on Specific Key Message Language and Supporting Text

The key messages are generally well written, consistent, and appropriate. They reflect the current understanding of the impacts of climate change in the Southeast on the economy, food systems, and human health. Assessments of likelihood are included in some key messages, but not in others—this should reflect the knowledge base rather than omissions. Additionally, key message titles are topics and should instead communicate a short message, making them more impactful.

The text supporting the key messages is generally well written and contains sufficient details that provide further evidence. Some detailed comments are available in Appendix A.

Key Message 22.1. Regional Growth, Change, and Equitable Climate Adaptation

The Southeast's population is growing, mostly in urban areas and along its coastline, putting more communities and their assets into harm's way from increasing risks related to climate and land-use changes (*very high confidence*). Decision-makers preparing for current and future risks frequently use outdated and/or limited information on climate-related risks (*high confidence*). Climate adaptation efforts tend to be concentrated in high-capacity communities, leaving under-resourced and more rural populations, communities of color, and tribal nations at a growing risk (*high confidence*).

The use of data included as part of this key message is not well explained in the text supporting this key message. The last section, "Uneven Use of Tools at Hand to Ensure Equitable Adaptation," could apply to every region and it is not necessary to include here, or at a minimum, should be cross-referenced with Chapter 31 (Adaptation).

Key Message 22.2. Human Health and Well-Being

Human health and climate stressors are intimately linked in the Southeast (*very high confidence*). Community characteristics, such as racial and ethnic population, chronic disease prevalence, age, and socioeconomic status, can influence how climate change exacerbates, ameliorates, or introduces new health issues (*very high confidence*). Climate change is already impacting health in the region (*very likely, very high confidence*). There are effective strategies to address the health impacts of climate change in the Southeast that have multiple benefits across social and environmental contexts (*high confidence*).

The last statement in Key Message 22.2 is not sufficiently explained in the supporting text.

Key Message 22.3. Livelihoods and Economy

Over the last few decades, economic growth in the Southeast has been concentrated in and around urban centers (*high confidence*) that depend on climate-sensitive infrastructure and regional connections to thrive (*medium confidence*). Simultaneously, rural and place-based economies that rely on the region's ecosystems are particularly at risk from current and future climate changes (*high confidence*). Global warming is expected to worsen climate-related impacts to the region's economic systems and labor, with disproportionate effects on under-resourced and historically marginalized communities (*high confidence*). A coordinated approach that recognizes present-day inequities and the interdependencies between rural and urban communities will be necessary to secure the region's economic vitality (*high confidence*).

No likelihood language is provided in this key message, which is also quite long compared to others in the draft NCA5 report. Additionally, the term "marginalized" can be harmful as it perpetuates feelings of inadequacy, and the Committee suggests instead, using standardized language across the report, such as "historically overburdened." In the text

supporting this key message, there should be more discussion about climate impacts on recreation.

Comments on Traceable Accounts

The quality of the traceable accounts varies. For some key messages, the description of the knowledge base is more thorough with citations, while other sections are short with no citations. The description of confidence and likelihood sections read as a restatement of the key messages rather than explaining the how and why of confidence/likelihood language. While the process described at the beginning of the traceable accounts section is thorough, the rest of the section should more consistently describe how the knowledge base supports the claims in the key messages. Relatedly, likelihood statements were assigned unevenly in this chapter, and if there are knowledge gaps that limit the use of likelihood statements, these should also be noted in the traceable accounts.

Comments on Graphics and Boxes

Graphics in this chapter are generally effective and appropriate, and many are easy to interpret for the intended audiences. Figure 22.5 is not specific to the region and unnecessary. In general, figure captions should be self-contained and walk the reader through the message of each figure. For example, Figure 22.10 is highly complex and requires additional explanation about how future warming would impact PM_{2.5} concentrations (not shown) and lead to excess premature deaths. Figure 22.16 is another example of a complex figure where only passing mention of the time period and warming scenarios are provided, proactive versus no adaptation are not defined, potential additional costs to energy consumers are not explained, and cost per megawatt hour over an unknown time period may not be understandable for general audiences.

Comments on Equity and Justice

The authors provide strong framing of equity- and justice-related issues in the chapter introduction. Important historical context is given, as well as the perspective of complex systemic interconnections. Vulnerabilities are not limited to racial and socioeconomic classes, but also include occupational and geographic vulnerabilities. Environmental justice issues are consistently integrated throughout the chapter. Additional attention can be given to the different dimensions of equity (i.e., distributional, procedural, recognition, intergenerational) and how they relate to specific issues discussed. In addition, the importance of data justice, the equitable availability and access to relevant data to support community climate action, should be addressed. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Data and Analyses

The data and analyses adopted from other sources and presented in this chapter seem appropriate.

Comments on Literature Cited

Overall, appropriate literature is cited. However, some references are outdated, particularly for those on past hurricanes. The region has experienced many more disasters since NCA4, and more recent literature should be cited accordingly.

Other Recommended Changes

The chapter spends a great deal of space on the health of people in the region broken out by risks yet does not include the widespread use of harmful natural resource extraction practices. The chapter could also build on NCA4 to report updated assessment of the region's infrastructure, for example, the region's lack of disaster preparedness and response infrastructure given the increased frequency of climate-related disasters.

Hypoxia is a major issue along the Gulf states, which affects the economy, commercial fishing, recreational fishing, and ecosystems. Climate change is considered a contributing factor, and this chapter should mention this issue.

More generally, there is very limited discussion on the Gulf of Mexico. Topics that could be added include salt-water and fresh-water inundation of coastal areas from tropical storms, hurricanes, general SLR and land subsidence, and hydraulic-induced encroachment of salt water into aquifers and communities in Florida.

CHAPTER 23: US CARIBBEAN**Summary**

Overall, the Committee commends the chapter authors on a standout chapter and for developing a translation of this chapter into Spanish to make it more accessible and inclusive (the Committee did not independently review the translated chapter). The chapter focuses attention on the vulnerability of the region to extreme weather events (hurricanes) and SLR and frames the vulnerability of people and infrastructure in terms of historical inequalities. Examples of adaptation highlight community-based grassroots efforts. The key findings, as well as information gaps, are clearly communicated at an appropriate technical level and are supported by evidence that is documented in a transparent and credible way. Additionally, the chapter analyzes the impacts of climate change on the US Caribbean (Puerto Rico and the US Virgin Islands) by integrating the evidence regarding current trends as well as projected trends for the future. The chapter, therefore, meets the requirements of Section 106 of the GCRA.

The chapter's key messages accurately reflect the current understanding of impacts and future vulnerabilities. The Committee commends the chapter authors for including a section on emerging issues, highlighting uncertainties in the main body of the text, not just the traceable accounts, noting the lack of climate data and research specific to the region—for example, the lack of high-resolution climate projections, and flood maps—making it difficult to accurately quantify impacts.

It is important to note, however, that Chapter 1 (Overview) does not completely reflect the climate justice emphasis of this chapter, although it does give examples of adverse climate impacts (Table 1.2) and threats to the economy as well as examples of community action (Table

1.1) from this region. Chapter 1 (Overview) does refer to this and many other chapters as giving examples of dispossession of Indigenous people (pages 1-20 to 1-21).

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The chapter introduction is exemplary. It is explicitly framed by the unique political history of the US Caribbean, where colonization, systematic inequalities, and racism have rendered natural environments, people and infrastructure particularly exposed to the impacts of climate change on health and well-being. The introduction, detailing the geography and history of the region, sources of social vulnerability, and observed and project climate change, provides important context and the appropriate background for audiences who may be unfamiliar with the US Caribbean. The Committee suggests, however, that the introduction also include a brief statement noting topics that are not covered in the chapter.

Comments on Key Messages, Supporting Information, and Traceable Accounts

Overall, the five key messages are comprehensive and encompass the key climate-related impacts on the region; the natural ecosystems and services they provide; food and water systems; and critical infrastructure. The key messages are similar to NCA4 but reflect updated events and information since 2018. However, consistent with the recommendation in Chapter 2 of this report, the Committee suggests formatting the titles of key messages such that they are short, informative statements rather than headers, thereby making them more effective. The Committee also suggests that authors consider including the discussion on climate change (pages 23-6 through 23-8) as a key message, which is the foundation of the following key messages. Chapter authors should then also include traceable accounts for the additional key message. This suggestion would help build consistency with some of the other chapters. Alternatively, the structure could remain as is because there are already five key messages, and the introduction to the region was useful in framing the chapter and key messages.

Comments on Specific Key Message Language

Key Message 23.1. Human Health, Quality of Life, and Well-Being

Traditionally underserved and disadvantaged communities suffer disproportionate impacts from climate change because they have been systematically excluded from social services, secure livelihoods, quality education, and other social benefits that help sustain health and well-being (*high confidence*). Hurricanes and other climate-related extreme events have been associated with higher rates of disease, mental illness, and overall mortality, as well as loss of cultural heritage that is central to community identity (*high confidence*). As extreme weather events become more intense and more frequent, residents will continue experiencing increasing levels of noncommunicable diseases, excess mortality, behavioral health challenges, and loss of quality of life (*high confidence*).

The Committee suggests making the title more explicit and impactful by adding “are Threatened by Climate Change Impacts” at the end.

Key Message 23.2. Ecology and Biodiversity

Coastal and terrestrial ecosystems provide a large number of goods and services that are vital to the islands’ economies and to the health and well-being of their residents (*high confidence*). These essential systems are degraded by human actions and climate change, thereby reducing the benefits they provide to people, as well as their functionality as habitats for protecting biological diversity (*high confidence*). Climate change is expected to exacerbate the degradation of ecosystems (*very likely, high confidence*). The success of climate adaptation strategies will depend on reducing all sources of stress on ecological systems (*medium confidence*).

The Committee suggests making the title more explicit and impactful by adding “are Unique and Vulnerable” after “Biodiversity.”

Key Message 23.3. Water and Food Insecurity

US Caribbean food and water systems are becoming increasingly vulnerable to the escalation of climate change, including stronger hurricanes, more severe drought, warmer air temperatures, and other extreme weather (*high confidence*). Because the territories are heavily reliant on imported foods, they are affected by climate changes occurring both within and outside of the US Caribbean region (*high confidence*). Mean rainfall reductions, increasing air temperatures, and sea level rise will adversely affect freshwater availability in the future (*medium confidence*). Better understanding of the ways food and water systems interrelate and of the cascading impacts generated by climate change is needed to improve adaptation efforts (*medium confidence*).

The Committee suggests making the title more explicit and impactful by changing it to “Climate Change Worsens Water and Food Insecurity.” Lower rainfall, higher temperatures, and SLR mean less freshwater available in the future. Reliance on imported food (80-90%) makes the region vulnerable to climate change impacts elsewhere. More drought and large hurricanes mean more crop failure and soil erosion.

Key Message 23.4. Infrastructure and Energy

Climate change has created profound risks for the US Caribbean’s critical infrastructure, already weakened from years of disinvestment and deferred maintenance (*high confidence*). Increasingly powerful storms, along with rising sea levels, are severely impairing infrastructure systems, with increasing damage projected in future years (*likely, high confidence*). Dependence of fossil fuel imports increases energy insecurity (*high confidence*). Infrastructure improvements, coupled with a new paradigm focused on decentralization, adoption of distributed solar, and shared governance, could help limit residents’ vulnerability to health and other risks associated with loss of essential services (*high confidence*).

The Committee suggests making the title more explicit and impactful by adding “are Vulnerable but Decentralization Could Improve Resilience.” Years of disinvestment have left

critical infrastructure vulnerable to extreme climate events. These systems and their governance are centralized, increasing their vulnerability. Decentralized systems with shared governance, and less reliance on fossil fuel imports (e.g., distributed solar), would increase redundancy and flexibility and people's climate resilience and local self-determination.

Key Message 23.5. Planning and Adaptation

Climate adaptation in the US Caribbean is challenging because of multiple interacting factors, including high risk exposure, limited or misaligned funding, insufficient institutional and organizational capacity, and siloed approaches to risk reduction and resilience (*high confidence*). Effective adaptation to support resilience in the US Caribbean could be enhanced through co-development and integration of robust global, regional, and local climate science and risk-based knowledge into planning and implementation, as well as improved governance arrangements (*high confidence*). US Caribbean capabilities in planning and adaptation can be enhanced by strengthening partnerships across the wider Caribbean region and the US mainland (*medium confidence*).

The Committee suggests making the title more explicit and impactful by adding “Face Institutional Barriers and Needs Improved Governance Structures.” Key Message 23.5 states that high risk exposure plus limited and siloed institutional capacity challenge planning and adaptation. Developing and integrating global- regional- and local-scale institutions, and regional partnerships, will support effective, equitable adaptation. This will require greater uptake of climate change information in public-sector planning and decision making.

Comments on Text Supporting the Key Messages

Overall, the text supporting the key messages is very effective, communicated at the appropriate technical level, and well cited, reflecting the knowledge base. The Committee appreciates the thoughtful work that the chapter authors put into crafting this chapter.

Key Message 23.1. Human Health, Quality of Life, and Well-Being. The Committee highlights that mentioning the “One Health” approach to mobilize collaborative work among communities, stakeholders, practitioners, sectors, and disciplines was a unique aspect of this chapter. Additionally, the Committee suggests that chapter authors consider adding one additional reference to support this key message, though noting that it is not region specific (Ibanez et al., 2022).

Comments on Traceable Accounts

The chapter authors describe the process of developing this chapter by assembling a large, diverse multidisciplinary team, hosting a public engagement workshop, and developing an evidence base founded in peer-reviewed literature, and acknowledge that much more literature is available for Puerto Rico than the US Virgin Islands. The confidences and likelihood statements expressed in the key messages are clearly explained in more detail in this section, and there is an important emphasis on needing high resolution climate change projections for the region.

However, the traceable accounts section does not cite any literature. As is consistent with the Committee's recommendation in Chapter 2 of this report, the chapter authors should apply

robust evidence (i.e., literature cited) to justify both the confidence likelihood assigned to each qualitative statement within each key message, and the supporting text, thereby providing credibility to each assertion. This chapter should strive to be consistent with other chapters in terms of citations in the key message text and in the traceable accounts section.

Comments on Graphics and Boxes

The graphics are generally informative and useful, but some of the captions should be expanded to better communicate the meaning of the figure.

Figure 23.4 is useful but does not appear to be cited in the text.

Figure 23.10 shows infrastructure at risk of flooding in the US Virgin Islands. It is very welcomed to see data from the US Virgin Islands in this chapter, but the figure could use more detail, if available. Additionally, the proportion of critical infrastructure in flood zones is shown, but there is no information about how a flood zone is defined, and if future SLR or storm intensity are taken into account.

Figure 23.11 shows the water use in Puerto Rico for human consumption versus power production but is relatively ineffective as a figure. The information could simply be stated in the text (it looks like power generation uses about one-third of water used) and the figure could be removed, making room for another figure. For example, if there are any models predicting climate change effects on aquifers, those projections might make a nice illustration. If not, it underscores the lack of data for the region.

Comments on Equity and Justice

This chapter does a standout job using an equity and justice framework and could be a useful example for other chapters. The chapter explicitly uses a framework of equity and justice to show that the vulnerability of the region results from a history founded in colonization and slavery leading to systematic inequalities and racism that have resulted in natural environments, people, and infrastructure that are particularly vulnerable to the impacts of climate change on health, resilience, and well-being. Impacts on cultural resources and traditional ecological knowledge are discussed. Adaptation and planning based on grassroots organizing, community-based responses, and distributed inclusive governance are assessed to be most likely to succeed in the region. The only recommendation is that the chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

Not all the literature cited is new since NCA4, although almost all of it is published in the past ten years. This may reflect a lack of available literature for the region that is more recent. Perhaps by necessity, much of the material is based on Puerto Rico, and the Committee suggests expanding the literature on the US Virgin Islands, if possible.

Other Recommended Changes

This chapter utilizes SLR projections from the IPCC AR6 report. This is not an issue in of itself, but Appendix 3 does not list IPCC SLR projections as a standard source of information.

Rather, SLR scenarios from the US Interagency Taskforce (ITF) Report (Sweet et al., 2022) were provided to chapter authors (see Chapter 9 Coastal Effects, although the authors of Chapter 9 were asked to include additional information about the IPCC SLR projections). To increase consistency across the report, an overall suggestion from the Committee is that authors across all chapters agree on an approach for discussing SLR, including agreeing on the sources of information to be used. Utilizing SLR information from both the IPCC and ITF is a good approach—each has its own use case—but care should be given to properly connect them, as the ITF scenarios do not map directly onto a single emissions scenario. More specifically, the IPCC SLR projections are most appropriate for providing information about uncertainty (or the range of possibilities), which this chapter does not discuss in detail. The Committee suggest that the authors of this chapter include more discussion of uncertainty (not only in regard to SLR) and that they do so beyond the context of the Very High Emissions scenario. Other emissions scenarios are possible and reasonable to include in a decision-making context. A good resource for chapter authors to explore the IPCC-based projections is the National Aeronautical Space Administration tool.¹⁶

Additionally, there may be opportunities for this chapter and Chapter 30 (Hawai‘i and US Affiliated Pacific Islands) to cross-reference each other given the similarities of the socioecological challenges the regions face driven by climate change.

CHAPTER 24: MIDWEST

Summary

This chapter addresses climate change risks, impacts, and adaptation in the Midwest region across five sectors or thematic areas. The chapter is well done, with a reasonably good connection between the key messages and the traceable account, and it addresses Section 106 of the GCRA. The key messages are provided in a logical sequence and provide a notable change from NCA4, which makes appropriate consolidation, but in so doing may have decoupled it from the sector-based chapters. It would be useful to reconcile and cross reference against Chapter 1 (Overview) and other chapters, particularly since the key message in NCA4 on transport and infrastructure is framed here as built environment, water is new, and forest and biodiversity have been combined. This chapter is improved by its inclusion of adaptation measures described within each key message as part of an internal structure that works well. Each key message is framed around a key message statement, risk, impacts, and an example domain for adaptation (and mitigation), although the Committee suggests considering a term other than risk, such as importance or significance.

The individual key messages use IPCC scenarios, which is a very good way to introduce the basis for prognostic analysis, but the authors should not use older SRES, since they are not mentioned in Chapter 1 (Overview), Chapter 3 (Earth System Processes), nor in Appendix 3 (Scenarios and Datasets). Key messages are well referenced but there are no references in the traceable accounts. The technical level of writing is appropriate, but authors may consider cross-referencing the IPCC scenarios found in Appendix 3 (Scenarios and Datasets). There is a tendency to write about climate conditions both empirically and through projections, so it should be made clear the distinction between natural variability and attribution to climate change (also

¹⁶ See <https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool>.

land-use change). For the most part this is well done, and references are useful for this (e.g., Key Message 24.1). The absence of discussion on biofuels is notable; the Committee suggests some additional text.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction provides a brief overview of the importance of climate change to the region but does less to summarize the findings or key messages, or the general message on climate change impacts. The basis for the introduction is that numerical models estimate increasing temperatures and more precipitation. It may be better to frame the introduction based on findings and important messages from other chapters that are examined here, such as Chapter 11 (Agriculture, Food Systems, and Rural Communities), Chapter 7 (Forests), and Chapter 12 (Built Environment, Urban Systems, and Cities), among others. The Committee recognizes that often material presented in this chapter is more extensive and perhaps more comprehensive than in the sector-based chapters, so cross referencing with sector chapters could make the overall report more consistent and more useful to the reader.

Comments on Key Messages, Supporting Information, and Traceable Accounts

This chapter examines the impact of climate change in the Midwest region. There are five key messages, which are presented in a logical sequence. The titles of the key messages are brief headings, although the descriptions are framed as messages. Agriculture is heavily emphasized and documented, which would be expected, but it is incomplete in its central focus on row crop agriculture. Perhaps this is due to there being less information on climate impacts for specialty crops and livestock, but more consideration would be good; Figure 24.2 is notable, providing a good starting point. Projections of climate change impact on natural resources and sectors are given (e.g., soil erosion, agricultural production, growing season characteristics), but far less on their economic impact. When done, they are good examples with high impact for the reader, and it would be interesting to include economic impacts for all these regional assessments. The treatment of natural resources impacts is done well, but many of the statements of impacts are very general, and there is little in the way of projection. The inclusion of the built environment is useful since the regional land-use and cover is diverse, with many urban centers that are large and growing. Community health considerations are good if somewhat general; analysis of inequities across communities and incomes should be emphasized more. Lastly, water is treated as an important key message, but the most important water element is the Great Lakes and that is not done as well as needed; some critical issues are in the climate impacts in the Lakes that could have profound regional and national impacts, including shoreline erosion, fisheries, and other indirect effects other than the stated direct effects (e.g., algal blooms). Key message discussions have a risk-impacts-adaptation format, which is very good, but different than other regional chapters. Cross-references to relevant sector-based chapters would be useful.

Many paragraphs are nicely worded to move from historical conditions and correlations, through current trends, to impacts and then projections of what could come, presented in time frames of mid-century and end of century. In general, although not fully followed everywhere in

text, the resulting discussion would be something readers can grasp, so adopting this style in other chapters would be useful for readership. When stating impacts, it would be better to frame them in language that speaks to the notion that evidence and analysis suggest the increased probability of the impact, but not as a deterministic outcome.

The text supporting the key messages is well written, with considerable and appropriate citations to the scientific literature. The chapter uses a three-part framework of risk, impacts, and adaptation (and example of the latter at work), which is nicely done but may not have been adapted for other regional chapters. The text uses projections to frame the impacts, which is very well done, but could be improved by using a standard time frame and ensuring a consistent use of scenarios. The use of the term “risk” could be substituted with “hazard,” “importance,” “significance,” or some other term that would be consistent with the text. It is important to make it clear in writing that what we know about climate change impacts is that it affects the probabilities of outcomes, rather than certain or deterministic outcomes, particularly in the context of natural variability.

Comments on Specific Key Message Language and Supporting Text

Key Message 24.1. Agriculture

Increasing precipitation variability, rising temperatures, and increasing atmospheric moisture are shifting crop growing zones, disrupting planting and harvesting schedules, and negatively impacting specialty crop production (*likely, high confidence*). Extreme precipitation events and transitions between wet and dry conditions are projected to intensify and reduce yields for some crops (e.g., corn and soybean), while overall increases in cooler-season precipitation will boost wheat production (*likely, medium confidence*). Changes in precipitation extremes, timing of snowmelt, and early-season rainfall are expected to pose greater challenges for animal agriculture, including disease transmission, muddier pastures, and further degradation of water quality (*likely, high confidence*). Climate-smart agriculture and other adaptation techniques provide a potential path toward environmental and economic sustainability (*medium confidence*).

Suggested title: “Climate Change Is Increasingly Disrupting Agricultural Production, But Adaptation Measures Already Exist.”

This is an exceptionally strong section. It uses the scenarios to provide projection information and links a detailed discussion of impacts directly to the risks discussion and key message statements. The adaptation example on climate-smart agriculture is appropriate and useful. The key message is that all aspects of climate change will affect agriculture, from rising temperatures, changes in atmospheric moisture, and shifting growing zones. The importance of extreme conditions and events are also highlighted. There is a heavy focus on differential impacts on corn compared to wheat, where corn is adversely impacted but wheat may benefit, which is a fair statement but perhaps simplified too much. Indeed, the key message notes wheat may benefit in terms of yield increases, but the situation is more complicated—for example, other regions (e.g., Northern Great Plains, Canada) may benefit more and complicate trade dynamics.

The complexities in agriculture are clearly noted, with a fair examination of negative and positive impacts. The reader is given a good understanding that issues are more complicated than simply having hotter temperatures and perhaps more rain. Perhaps this warrants a summary

paragraph which ties together the impacts discussion and relates it back to the key message. One of the complexities for agriculture, among other facets of this chapter, is the interrelationship between climate change and natural variability. It is important in noting impacts that the attribution is clearly pointed to climate change, or the natural background is recognized as appropriate. Similarly, the growing season effects, the so-called warming hole, and land-use change create complexities for management that may warrant a separate statement on complexities and management challenges for farmers and leads into the climate-smart agriculture discussion. The region is notable for specialty crops, and, although mentioned, perhaps more discussion on high-value specialty crops is needed. Similarly, the focus on row crop agriculture, for which most data exist, should be extended to orchards, tree-based systems, and livestock. It is surprising that there is so little discussion of biofuels. The mitigation and adaptation solutions rest on climate-smart agriculture but some reference to climate-smart forestry could be useful here, with reference to Key Message 24.2. The key message statement, “Increasing precipitation variability, rising temperatures, and increasing atmospheric moisture are shifting crop growing zones, disrupting planting and harvesting schedules, and negatively impacting specialty crop production (*likely, high confidence*),” is an example of language that could be more precise, because climate change can increase the odds of these events happening, but does not predetermine that they will. This sentence should also clarify whether the confidence and likelihood statements pertain to all items in the list.

This section has a notable lack of information on equity and justice, which could be expanded.

Key Message 24.2. Natural Resources

Ecosystems are already being affected by changes in extreme weather and other climate-related changes, with negative impacts on a wide range of species (*likely, high confidence*). Increasing incidence of flooding and drought is expected to further alter aquatic ecosystems (*likely, medium confidence*), while terrestrial ecosystems are being reshaped by rising temperatures and decreasing snow and ice cover (*very likely, high confidence*). Loss of ecosystem services is undermining human well-being, causing the loss of economic, cultural, and health benefits (*medium confidence*). In response, communities are adapting their cultural practices and the ways they manage the landscape, preserving and protecting ecosystems and the services they provide (*low confidence*).

Suggested title: “Climate Change Will Adversely Affect a Wide Variety of Species and Ecosystems, with Diminished Ecosystem Services.”

This is a well-written section that describes the region’s diverse natural resources. This key message appears to replace Forests and Ecosystems (Key Messages 2 and 3) from NCA4, which is a good thing, as it presents a broader framework. It may, however, lose some direct connection to the sector chapters unless they are specifically reflected and referenced in the text (common concepts and conclusions could be made and linked). The context could be broadened to include the Great Lakes ecosystem, and more on other natural systems such as grasslands and wetlands. The heavy emphasis on ice covered lakes and winter use of natural resources may not be necessary, unless more explicitly and clearly tied to warming and if good projections with quantitative impacts can be cited. Natural climate solutions are used as the example of adaptation/mitigation measures with respect to natural resources in this key message, and thus

are distinguished from climate-smart agriculture used in the previous key message on Agriculture. Both frameworks include adaptation and mitigation, and while it is useful to apply both in the way the authors have, it would also be useful to describe why the distinction is made. Perhaps also consider discussing nature-based solutions, since they directly relate to biodiversity. This key message should use language that conveys the idea that climate change increases the odds that impacts will occur.

Key Message 24.3. Health and Community Well-Being

Climate change is already having negative impacts on human health and well-being (*very likely, very high confidence*), with wide-ranging effects on livelihoods, health care, and community cohesion (*high confidence*). Because of historical and systemic biases, communities of color are especially vulnerable to these negative impacts (*very likely, very high confidence*). Mitigation and adaptation strategies such as increased urban tree cover and improved stormwater management, when developed in collaboration with affected communities, have the potential to improve health and bolster community well-being (*high confidence*).

Suggested title: “Climate Change Will Adversely Affect Human Health and May Enhance Health Disparities.”

This is a newly framed key message from NCA4 and benefits from an expansion to include community well-being but could elaborate the text to include a broader health framework, beginning with a cogent definition or description of community well-being. It recognizes the heterogeneity of the region and is strong on the equity and justice elements. The key message relies on a few coherent examples of health effects (e.g., Lyme disease), but could elaborate to include a broader health framework.

Key Message 24.4. Built Environment

Increases in temperatures and extreme precipitation events are already challenging aging infrastructure and are expected to impair surface transportation, water navigation, and the electrical grid (*likely, medium confidence*). Shifts in the timing and intensity of rainfall are expected to disrupt transportation along major rivers and increase chronic flooding (*likely, high confidence*). Green infrastructure and other public and private investments may mitigate losses, provide relief from heat, and offer other ways to adapt the built environment to a changing climate (*medium confidence*).

Suggested title: “Climate Change Has Costly Impacts on Infrastructure, But Green Development Solutions Exist.”

This new key message transforms the previous focus on transportation infrastructure into the built environment and makes the chapter stronger as a result. However, there is an inconsistency with Chapter 1 (Overview), which focuses on infrastructure, as in NCA4. The adaptation example and focal point on investments and finance are very good. The text on green finance should be developed more. There is no mention of mass timber. Also missing are discussions on how the built environment is growing and increasingly converting natural ecosystems and expanding the wildland urban interface.

Key Message 24.5. Water

Climate-related changes to water quantity and quality are increasing the risk to ecosystem health, adequate food production, and recreation (*high confidence*). Projected increases in drought, flooding, and runoff across the Mississippi River basin and the Great Lakes will adversely impact ecosystems through enhanced erosion, harmful algal blooms, and expansion of invasive species (*likely, high confidence*). Federal and state agencies and NGOs are cooperating on adaptation efforts related to streamflow, water quality, and other water issues (*high confidence*).

Suggested title: “Climate Change Will Likely Adversely Affect the Quantity and Quality of Water for Consumption, Economic Use, and Recreation.”

Water quality and quantity aspects are highlighted in this region, particularly for use in agriculture and in urban areas. The focus is on direct water quality impacts such as erosion and algal blooms. There is less attention to the Great Lakes, which has its own problems that are uniquely important to the region and should be discussed.

Comments on Traceable Accounts

There are no citations in the traceable accounts; the traceable accounts should include citations to explain how the knowledge base supports the key messages. The logic of the traceable accounts, however, is well done. The traceable account section for Key Message 24.1 is the most complete. It is important to make clear to the reader what is known about attribution directly to climate change and what is not. One of the most important challenges in climate change research has been the suitability and certainty of scaling down to regional or local impacts. The science has improved, but it remains a challenge. Therefore, some additional language on how certainty levels off at scale, and where the scale (as opposed to thematic) gaps exist in the literature for this region would be appropriate. It is important to use region-specific data and analysis and describe when proxies are used.

Comments on Graphics and Boxes

The figures and graphics are useful, to the extent that they have been presented. The lack of figures in many cases limited the review and as figures do become available, the author team should be aware of the lack of review.

Comments on Equity and Justice

For consistency, the Committee suggests that the chapter introductions frame equity and justice in the context of the chapter topic and include how different dimensions of recognition, procedure, and distribution are addressed. Consistent with recommendations in Chapter 2 of this report, terminology should be specific and consistent throughout the chapter. The discussion of equity and justice issues could be improved by more consistent integration throughout the chapter. A good review of existing literature on health and food disparities would help. In the introduction and throughout the sections, more attention needs to be paid to environmental justice concerns. Some statements refer to Indigenous groups, but there should be a stronger emphasis on both Indigenous and other vulnerable populations throughout the chapter. Only Key

Message 24.3 includes reference to communities of color, for example. Page 24-24 does have some discussion that more vulnerable people will be more heavily impacted. In addition, the importance of data justice, the equitable availability and access to relevant data and information to support community climate action, should be addressed. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Data and Analyses

The chapter uses models to project hazards onto key biophysical parameters such as water temperature and runoff, but less so for other parameters. This chapter does a good job documenting sources of statements (e.g., Key Messages 24.1 and 24.2).

Comments on Literature Cited

This chapter does a reasonably good job documenting sources of statements in the text on key messages, but not in traceable accounts.

Other Recommended Changes

Key gaps include almost no discussion of the growth of biofuel use and production in the Midwest, how climate change is affecting biofuels, and what is projected for the future. Another key gap is the lack of discussion of wind power growth in the Midwest, and its relation to farm incomes, land-use, biological systems, and the distributed grid.

The chapter fails to note connections to other regions. For example, the discussion of major rivers does not mention how dependent the flow of the Missouri and lower Mississippi are to that of the Rocky Mountains and the Ohio and Tennessee rivers.

The “warming hole” text is confusing, and the other interesting aspects should be emphasized more—for example, an increase in spring and fall temperatures would cause an increased growing season, which would impact an early bud break that has an impact on outright crop failure, or the wet early springs would delay planting. Thus, there are complexities, especially in agriculture, that should be discussed; some impacts may not be known, but what is known is that there could be considerable unintended consequences and surprise events. Is it also appropriate for the text and traceable accounts to note knowledge gaps.

Similarly, more attention should be paid to the important role that natural variability plays. For example, page 24-3, lines 15-17, states, “By about 2050, temperatures across the Midwest are expected to increase between 3°F and 5°F under an intermediate scenario (RCP4.5) relative to 1986-2015, with more than an 8°F increase projected by the end of the century under a very high scenario (RCP8.5) (Hayhoe et al. 2018).” There should be caveats on this statement because there are large uncertainties and natural variability in these estimates, and a reference to how uncertainty and interannual variability grows when looking at smaller regions in Chapter 3 (Earth System Processes) would be appropriate. Additionally, the reference for this statement should be revised to reference current climate projections directly rather than relying on results presented in NCA4.

CHAPTER 25: NORTHERN GREAT PLAINS

Summary

Overall, this chapter is well written, thorough, and comprehensive, with only a few omissions that need attention. The Committee commends the chapter authors for including recent developments in this chapter, such as the Inflation Reduction Act. The chapter also has a good balance of both positive and negative aspects of expected impacts from climate change, especially compared to Chapter 1 (Overview). This chapter is close to meeting the requirements of Section 106 of the GCRA, and, with additions and revisions specified here, the Committee believes it will meet those requirements.

For the most part, the key messages are well stated and supported by the detail provided within the chapter. However, some key messages are too detailed or too broad and lack support in the text of the chapter. Additionally, some important regional trends are omitted altogether. Suggested literature and topics for inclusion are detailed below. Mitigation is a key omission in the chapter; one of the last two key messages should discuss mitigation efforts in the Northern Great Plains. The chapter couches the discussion of energy and energy transition topics as “the transition from fossil fuels to renewable energy sources” (see page 25-22, lines 3-4). This is not an accurate representation of what is occurring or the content of other chapters (e.g., Chapters 5 [Energy Supply, Delivery, and Demand], 32 [Mitigation]). In addition to the buildout of renewables, there is a push for low- and zero-carbon technology deployment in the Northern Great Plains region.

Most of the chapter is written at a technical level that is appropriate for the intended audiences. The Committee calls out specific language concerns in Appendix A. The Committee suggests the chapter authors cross reference other chapters where possible (e.g., Key Message 25.4 could reference Chapter 18 [Sector Interactions, Multiple Stressors, and Complex Systems]), which not only emphasizes the inherent connection between topics, but also may help lower the word count in some places to make space for important additions. The traceable accounts section does not document and support chapter’s findings in a consistent, transparent, or credible manner and needs significant work to provide sufficient context for embedded content. Specific suggestions are provided below.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction should add context for the reader, especially considering the target audiences may be broad, and as defined in Chapter 2 of this report, includes decision makers, professionals, professors, teachers, and students with varying previous exposure to climate change literature. At the outset, the Northern Great Plains should be defined and the states that fall within the boundaries should be listed. This could also be done with a figure (e.g., “The NGP is one of the ten regions designated in the NCA5. It includes Montana, Wyoming, North Dakota, South Dakota, and Nebraska. See Figure ____.”). Additionally, the distinction between natural variability and climate change should be described and better called out throughout the chapter, but also within the introduction. While the topical discussion in the introduction sets the stage

nicely for the key messages that follow, the chronology of the introduction could better match the content of the chapter text.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The key messages in the Northern Great Plains chapter reflect the current understanding of observed and projected climate impacts to the United States; however, the Committee suggests improving the clarity of language that describes whether the projected and observed changes are due to climate changes, natural variability, or both. The chapter discusses challenges, opportunities, and success stories for addressing risk and adapting to emerging issues related to climate change. Regarding formatting, the key message titles, as outlined in Chapter 2 of this report, would be more effective if they were short, informative statements rather than headers; the Committee makes suggestions for each key message titles below. The messages within each key message are written in a consistent and appropriate way and they reflect supporting evidence, include an assessment of likelihood, and communicate information effectively. However, some of the text in the findings is too inclusive or broad, and the topics discussed are not reflected in the supporting text (e.g., “spiritual health” in Key Message 25.2 is not mentioned in the bulk of the text under Key Message 25.2). Where there is uncertainty (documented in the traceable accounts) this may be worth mentioning in the supporting text.

Comments on Specific Key Message Language

Key Message 25.1. Trends and Extreme Events

The Northern Great Plains is experiencing unprecedented extremes related to changes in climate, including severe droughts (*likely, high confidence*), increases in hail frequency and size (*medium confidence*), floods (*very likely, high confidence*), and wildfire (*likely, high confidence*), with alterations in plant community and crop growth (*very likely, very high confidence*). Rising temperatures across the region are expected to lead to reductions in soil moisture, even in areas with increasing precipitation (*likely, high confidence*), as well as greater variability in precipitation (*very likely, high confidence*).

Suggested title: “Climate Change Is Expected to Continue to Cause Unprecedented Extreme Events.”

Key Message 25.2. Human Health and Ecological Condition

Climate-related hazards, such as drought, wildfire, and flooding, are already harming the physical, mental, and spiritual health of Northern Great Plains residents (*virtually certain, high confidence*), as well as the ecology of the region (*very likely, medium confidence*). As the climate continues to change, it is expected to have increased and cascading negative effects on human health and the lands, waters, and species on which people depend (*very likely, medium confidence*).

Suggested title: “Extreme Events Caused by Climate Change Damage Human and Ecological Health and These Impacts Are Expected to Increase.”

Key Message 25.3. Resource- and Land-Based Livelihoods

The Northern Great Plains is heavily reliant on agriculture and resource-based economies, placing residents' livelihoods at risk from the impacts of climate change and related policy. While agriculture and recreation will see both positive and negative effects of changing temperature and precipitation regimes (*likely, medium confidence*), climate-driven extreme events will continue to cause substantial and unpredictable damages (*likely, high confidence*). Energy-sector livelihoods will be affected by climate change as emissions-reductions policies drive shifts to renewable energy sources and away from nonrenewable sources (*likely, high confidence*). Climate change is expected to test the adaptive resilience of the region's residents, in particular rural, Indigenous, and low-income immigrant populations (*likely, medium confidence*).

Suggested title: "Climate Change, and Climate Adaptation and Mitigation Efforts, Are Expected to Impact Resource- and Land-Based Livelihoods."

The text of this message uses the limiting language "renewable energy sources" and "nonrenewable sources," which is not consistent with other chapters in the report that discuss a wider array of energy generation and do not limit the discussion to renewable and nonrenewable generation. This exclusive focus on renewable energy is also not representative of what is occurring within the region. In addition to widespread renewable deployment, the states in the Northern Great Plains are also undertaking carbon capture, utilization, and storage (CCUS), nuclear, hydrogen, and other low- and zero-carbon technologies. The Committee suggests that chapter authors revise this part of the key message to be more representative of the regional energy portfolio.

The statement in Key Message 25.3, "energy sector livelihoods will be affected by climate change as emissions-reductions policies drive shifts to renewable energy sources and away from nonrenewable sources (*likely, high confidence*)," conflicts with Key Message 32.3, "A US energy system with net-zero emissions would rely on widespread electrification of transportation, electrification of heating in buildings and industry, decarbonized electricity systems, and substantial electricity generation from solar and wind (*high confidence*). Low-carbon fuels would still be needed for some transport and industry applications (*high confidence*)," and Key Message 32.3, "Although many mitigation options are currently available and cost-effective, the optimal mix of energy sources and technologies in net-zero emissions energy systems depends on still-uncertain technological progress, public acceptance, and future developments in institutions, markets, and policies (*high confidence*). The ideal approaches to carbon management—including both carbon capture and storage and carbon dioxide removal—are similarly uncertain (*high confidence*), as is the potential to reduce land-related methane and nitrous oxide emissions through technical interventions (*medium confidence*)." These conflicts between chapters should be resolved, and facts should be cited and mentioned in Chapter 25 (Northern Great Plains).

Key Message 25.4. Navigating Complex Tensions and Trade-Offs

Climate change is creating new and exacerbating existing tensions and trade-offs between land use, water availability, ecosystem services, and other considerations in the region, leading to decisions that are expected to benefit some and set back others (*very high confidence*). Decision-makers are navigating a complicated landscape of shifting demographics, policy and regulatory tensions, and barriers to action (*high confidence*).

Changes in temperature and precipitation averages, extremes, and seasonality will alter the productivity of working lands, resulting in land-use shifts to alternative crops or conversion to grasslands (*likely, medium confidence*). Shifts in energy demand, production, and policy will change land use for renewable and nonrenewable energy infrastructure (*likely, medium confidence*).

Suggested title: “Climate Mitigation Efforts Require Complex Trade-Offs Because Climate Change Will Likely Alter Resource Availability Differently Across the Region.”

This key message is very long and vague and should be refocused on mitigation efforts and trade-offs (see supporting text discussion). The Committee also suggests rewriting the message part of the key message to reflect first what is certain from a mitigation standpoint, then discuss what is uncertain.

Key Message 25.5. Building the Capacity to Adapt and Transform

Early adaptation is under way to address the effects of climate change. Agricultural communities are shifting toward climate adaptation measures such as innovative soil practices, new drought-management tools, and water-use partnerships (*medium confidence*). Several tribal nations are leading efforts to incorporate traditional knowledge and governance into their tribal adaptation plans (*high confidence*). Resource managers are increasingly relying on new tools such as scenario planning to improve the adaptive capacity of natural ecosystems (*medium confidence*).

Suggested title: “Climate Adaptation Efforts Are Already Under Way.”

Comments on Text Supporting Key Messages

Key Message 25.1. Trends and Extreme Events. Regarding drought, the text is not clear. The message of this key message says that increased temperatures are expected to offset increased precipitation, while the supporting text states that soil moisture will decrease in the southern part of the region. However, the more in-depth discussion on drought on page 25-10 does not address subregional differences. Thus, the key message implies increased temperatures are expected to offset increased precipitation across the region, but there are nuances not captured by the supporting text. The Committee suggests clarifying whether this trend is expected everywhere or just within some parts of the region. Additionally, this chapter does not cover the trend of corn production (monoculture practice) moving into South and North Dakota. This is a concern for adaptation because corn, which is a trademark of this region, is more sensitive to extreme events and requires higher inputs of chemical treatments than other crops (suggested literature for this topic is included below).

Key Message 25.3. Resource- and Land-Based Livelihoods. This key message uses “likely” and “high confidence” for the statement that “energy-sector livelihoods will be affected by climate change as the emissions-reductions policies drive shifts to renewable energy sources and away from nonrenewable sources.” However, there is no discussion of the mitigation efforts under way that are impacting and will continue to impact, energy sector livelihoods. The Committee suggests adding a discussion about mitigation to Key Message 25.4.

Key Message 25.4. Navigating Complex Tensions and Trade-Offs. Mitigation is a critical omission from the chapter. The supporting text for this key message discusses mitigation

efforts, so the Committee suggests stating mitigation in the title of the key message as well as the content of the message and the supporting text. The supporting text for this key message is broken into “renewables” versus “nonrenewables” without consideration of emerging low- and zero-carbon energy technologies (discussed in other chapters, such as Chapters 1 [Overview], 5 [Energy Supply, Delivery, and Demand], and 32 [Mitigation]) and presently being implemented and deployed by commercial, state, and federal actors in the Northern Great Plains region.

The Committee suggests no separate section headers for tensions and trade-offs, and instead to include all topics under no header (they are all tensions and trade-offs) and discuss the following: navigating barriers to mitigation; transition in energy systems; and land-use change and conversion including, agriculture to grassland, energy land-use changes, and shifts in crops.

Key Message 25.5. Building the Capacity to Adapt and Transform. The supporting text for this key message is missing a discussion on energy, particularly given that Key Message 25.3 notes that the region’s share of employees working in fossil fuel extraction is four times greater than the nation as a whole. The key message would benefit from a discussion about how adaptation and mitigation will impact this workforce.

Comments on Traceable Accounts

Because the traceable accounts section lacks citations and explanation, the chapter does not identify and provide sufficient context for embedded content, and it does not yet reflect current scientific understanding. The traceable accounts should be revised to demonstrate *which* references support *each* confidence and likelihood statement under each key message. Each key message’s traceable account should make modifications based on the outline for traceable accounts provided in Chapter 2 of this report.

In addition to the broad guidance in the introductory chapter, the Committee makes the following suggestions for each key message’s traceable account section to ensure the section provides sufficient context for embedded content and reflects current scientific understanding.

In Key Message 25.1, the NOAA State Climate Summaries should be cited in the supporting text if used in the traceable account, and if they are, the same citation should appear here. The Committee offers the same comment for US Geological Survey trend and attribution efforts mentioned. The note that the Northern Great Plains region also includes other water basins is a great distinction. Every time a study, an independent scientific assessment, an analysis, or other documents in the literature is discussed, it should be cited. All mentions of uncertainty and gaps should also have citations. The second paragraph is exemplary and should serve as a model for the whole of the traceable accounts section. The paragraph discussing the productivity of rangelands needs citations and a discussion about how authors came to their conclusions.

For Key Message 25.2, the Committee suggests ensuring literature with a national or international scope noted as such in the text and gaps in knowledge regarding the region as well as differences across the region are noted. For example, the citations on increased mental health in the region (page 25-12, line 31) seem to have a national scope rather than a focus on the Northern Great Plains.

For Key Messages 25.2, 25.3, 25.4, and 25.5, all summary statements referring to “several studies,” “NOAA state climate summaries,” and “multiple peer-reviewed studies” need citations, and the references should also be cited in the summary text. The traceable accounts should not introduce new literature not already cited in the main text.

Comments on Graphics and Boxes

The graphics and captions are effective and appropriate, but several changes would facilitate greater clarity and utility across audiences. Specifically, the following figures could benefit from modifications outlined below.

The title of Figure 25.1 should have a slash between tribal reservation and trust lands to improve the clarity of the text “Rurality Measures and Tribal Reservation/Trust Land in the NGP.”

The Committee suggests including state boundaries in Figures 25.2, 25.4, and 25.5 in grey/black on regional images so that it is clear where impacts are most severe. Likewise, Figure 25.6 should include state boundaries in grey/black on regional images to emphasize geographical differences across states. Additionally in Figure 25.5, the Committee suggests moving change to the bottom, so the image reads start (2004-2010) to end (2011-2015) and with change after. Figure 25.6 should indicate for each that they are displayed by county (or whatever regional delineation is used) for the farmland map and the social vulnerability map. Additionally, indicate what A, B, C, D, and E refer to on the social vulnerability map (e.g., “Examples detailed in later text are called out using A-E”).

In Figure 25.3, notating the watershed regions with lines instead of brackets would make the figure clearer. In the caption, instead of “less than 0.85” use “less than 85 out of 100” for consistency with the previous sentence.

In the caption for Figure 25.10, change “averages” to “means.” This image may be trying to do too much. Consider naming each image A, B, and C to differentiate that they are all different pieces and not one image. Alternatively, label the bottom image the key. Additionally, the Committee suggests moving the image to after all the text in this section.

Comments on Equity and Justice

This chapter could benefit from some framing of equity and justice-related issues in the introduction, including the different dimensions of equity. Specific issues should then be integrated throughout the chapter. Identify the range of vulnerable populations and provide some systemic context. The chapter contains a discussion of adaptation by Indigenous communities and has some examples of tribal adaptation and vulnerable population risk due to extreme events caused by climate change. It contains some discussion of the vulnerability of Indigenous communities to adaptation, particularly in food and agriculture. However, risks to vulnerable communities, particularly energy-sector workers (see discussions above) and low-income rural communities are not addressed and should be added. The Committee also suggests using consistent terminology to discuss vulnerable populations, tribal populations, and other populations of concern across all chapters, as there is a great deal of variety across chapters. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

This chapter does accurately reflect the peer-reviewed scientific literature or other source information cited, with a particular focus on literature since NCA4, but there is one concerning citation. The water rights discussion in “Adaptations in Agriculture” needs clarification, revision,

and additional attention. There is a citation to “confusing water law” in the “Navigating Barriers to Adaptation” section (Charnley et al., 2020) that does not support the sentence it is used in—it does not discuss water rights in detail and to the extent it does, they are not applicable because the paper’s case study is in the Northwest, not the Northern Great Plains.

The Committee also suggests clarifying language throughout the chapter to reflect where the trends are national versus regional. For instance, the mental health section text states that climate change is expected to amplify risks to mental health. This statement could be interpreted as applicable to the Northern Great Plains region since this is a regional chapter, but the citations are national-level and global-level studies (this section is citing Burke et al. [2018] and Yazd et al. [2019]). The Committee suggests looking for additional resources that are newer than 2014–2016 or refining confidence language to reflect older literature, particularly in the “Water Quality” discussion.

Other Recommended Changes

The chapter authors may consider the following notes for further improvements to the chapter. The chapter reads somewhat choppy and disjointed, especially compared to other chapters. Some sections would benefit from transition phrases, words, and sentences to add clarity and ensure broad comprehension. Using active voice where possible will also help; some sentences could benefit from an active voice rewrite (identified in Appendix A where possible). Other sections read very smoothly and have adequate active voice. Some other regional chapters (e.g., Chapter 22 [Southeast]) have addressed baseline trends and a discussion of “trends” in population, land-use, urban growth, etc., which if provided here could nicely set the context for the regional discussion.

For the most part, this chapter accurately reflects the peer-reviewed scientific literature. However, a few topics are not discussed. Mitigation is a critical omission from the chapter and is discussed above. The literature on the movement of the corn belt is also an omission and is discussed above. The Committee also suggests mention of wildfire impacts to albedo, snowmelt, and compounding impacts to flood risk and landslides.

CHAPTER 26: SOUTHERN GREAT PLAINS

Summary

Overall, the Committee commends the chapter authors for developing an exemplary chapter. The chapter does a great job of discussing the issues facing the Southern Great Plains region and is written at an appropriate technical level for the intended audiences. The chapter meets the requirements of Section 106 of the GCRA. In general, the key findings are well stated and supported. However, the key message titles are headers and should be revised to short, informative statements. Additionally, the chapter uses football to provide tangible connections to climatic extremes felt throughout the region, and the Committee suggests varying its examples to include other important activities in the region. The chapter does not adequately incorporate equity and justice principles. Specifically, there are issues associated with tribal lands relating to equity, mitigation and adaptation that should be discussed. There is also no discussion on the

distributional impact of the transition from fossil fuels to zero and low-carbon technologies on workers and industries in the region.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction is well written, describes the region well, provides the appropriate background and context to the region as it relates to climate change, and introduces the key messages. However, it would be helpful to introduce which states comprise the Southern Great Plains region, for example, with a figure. Additionally, the introduction should highlight new information since NCA4 as well as note topics that will not be covered in the chapter. Figure 26.1 on precipitation intensity does not support the statement of more frequent high-intense rain events in Kansas and Oklahoma. There are other figures that better illustrate the change in precipitation events. While energy as the driver of the region's economy is emphasized in the introduction, agriculture should also be included as it is a major contributor to the region's economy.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The key messages in Chapter 26 (Southern Great Plains) reflect the current understanding of observed and projected climate impacts to the United States; however, the titles of the key messages should be revised to stand out as short, informative statements. This suggestion is consistent with the recommendation provided in Chapter 2 of this report.

Comments on Key Messages and Supporting Text

Key Message 26.1. How We Live: Impacts to Place, Culture, and Health

Climate change is beginning to alter how we live, putting us at risk from climate hazards that degrade our lands and waters, quality of life, health and well-being, and cultural interconnectedness (*high confidence*). These hazards are expected to become more frequent, intense, prolonged, or broader in spatial extent and to result in more people experiencing costly, deadly, or stressful climate-related conditions in their lives (*very likely, high confidence*). Effective climate-resilient actions include implementing nature-based solutions; valuing Indigenous, traditional, and local knowledges; and infusing climate change solutions into community planning (*medium confidence*).

The title of the key message is written as a header instead of a statement. The Committee suggests slightly modifying the first sentence of the key message and using it as the title (e.g., "Climate change is beginning to alter how we live, degrading lands and waters, quality of life, health and well-being, and culture interconnectedness"). In this key message, the chapter authors should also consider the increased incidents of grassland wildfires. Over the past few years, large-scale fires have destroyed cattle herds, and infrastructure (e.g., fencing, homes) and even caused human deaths, and this should be noted.

Key Message 26.2. How We Work: Impacts to Business and Industry

As climate conditions change, businesses and industries across the Southern Great Plains are experiencing disruptions and losses in productivity and profits—but also new economic opportunities (*high confidence*). In coming decades, warmer temperatures, more erratic precipitation, and sea level rise are expected to force widespread and costly changes in how we work (*very likely, high confidence*). Businesses and industries have the opportunity to harness their diverse knowledge, resources, and workers to develop products and services in climate mitigation technologies, adaptation strategies, and resilient design that will enhance the region’s economy (*medium confidence*).

The title of the key message is written as a header, but the first sentence of the key message would be an effective title.

This key message emphasizes the transition to renewable energy, stating on page 26-11: “Throughout the region, a major shift in energy generation from fossil fuels toward renewables (KM 5.3) is underway, creating new jobs, cleaner air, and climate change mitigation benefits.” The Committee suggests including a discussion of the distributional impact on those workers who used to work in the fossil fuel industry in this section. For example, electricity from coal might not increase, but is it expected to decrease, and the effect on jobs in the region should be noted.

To add a specific example to the text supporting this key message, the chapter authors could use the example of when an early heat wave killed several thousand cattle in southwest Kansas in April 2021. The early heat wave was before the regular notifications went out from NOAA of the heat index for cattle. Another important agriculture issue to note in this section is that the western region of the Southern Great Plains is irrigated agriculture from the Ogallala aquifer. The combination of lower precipitation and a declining aquifer will cause dramatic changes in agriculture production and rural communities’ economy. An example of the impact on agriculture that could be discussed is the drought in 2011-2012 that reduced the feed supply to livestock, resulting in the livestock being transported to the Northern part of the Great Plains. This caused an increase in cost (transportation) and, ultimately, a decrease in the cattle herd.

Key Message 26.3. How We Play: Impacts to Recreation, Sport, and Leisure

Extreme climate-related events are negatively influencing how we participate in outdoor sport, recreation, and physical activities across the Southern Great Plains (*very high confidence*). Climate change is expected to increase heat-related illness and death and reduce outdoor physical activity (*very likely, high confidence*). Individuals, communities, and sports organizations can adapt to these hazards through strategies such as modifying the timing, location, intensity, or monitoring of activities (*high confidence*).

The title of the key message is written as a header, but the first sentence of the key message would be an effective title. The Committee appreciates the example where recreational activities are affected by climate change. However, the example of college football being impacted by hurricanes and extreme rainfall events supports a stereotype of the region. A better example would be to show the impact of the relocation of families affected by hurricanes.

Key Message 26.4. How We Heal: Impacts to Justice and Equity

Some neighborhoods and communities in the Southern Great Plains are suffering disproportionately from climate-related hazards because of marginalization, discrimination, governmental policies, and exposure to pollution and environmental degradation (*very high confidence*). Climate change impacts are expected to overburden the people, neighborhoods, and communities with the fewest resources to prepare and adapt (*very high confidence*). Our institutions and governments can improve outcomes for these people and places by adopting climate adaptation and hazard mitigation practices and policies that center on equity and justice for community risk reduction, resilience, and repair from past injustices (*medium confidence*).

The Committee suggests using the first sentence of the key message as the title.

Key Message 26.5. How We Serve: Impacts to Services and Public Infrastructure

The institutions that serve our communities have been challenged to respond and adapt to more frequent and intense weather events (*medium confidence*). Without significant adaptations, climate change is expected to strain water supplies, transportation infrastructure, and emergency services across the Southern Great Plains (*high confidence*). Actions that can enhance our community resilience include substantially reducing emissions; installing or retrofitting climate resilient infrastructure; educating students and the public on climate change impacts; and cultivating the capacity of faith- and volunteer-based aid organizations to assist hazard planning, response, and recovery (*medium confidence*).

The Committee suggests using the first sentence of the key message as the title.

Comments on Traceable Accounts

The traceable accounts for Chapter 26 (Southern Great Plains) provide accurate and sufficient support for the embedded content, including providing sufficient justification of confidence levels based on literature cited. The “Major Uncertainties and Research Gaps” sections should cite literature that was introduced in the main body to support the discussion.

Comments on Graphics and Boxes

The graphics and captions are effective and appropriate; however, the Committee has a few minor suggestions to help make them more accessible to broader audiences.

Figure 26.1 states, “Since 1985, 2-inch precipitation events have occurred more often than in the past in Kansas and Oklahoma.” It is unclear, as presented, if this trend is significant. The Committee suggest providing some clarification.

Figure 26.2 should use the standard labels for RCP4.5/RCP 8.5 (intermediate/very high), instead of calling these “lower emissions” and “higher emissions” as was done in NCA4.

The title of Figure 26.4 should reflect whether this figure is for this region only or is more general.

Figure 26.10 lists the sources in its caption as “University of Oklahoma, NOAA NCEI, and CISESS NC.” It is important to note if the data used to create this figure also came from these sources, and if so, they should be included in the reference list.

Figure 26.14 extends the stereotype of the importance of football in the region. A more appropriate figure could be used to communicate to the reader the impact of extreme events and society.

Figure 26.17 should define and explain “ILCP.”

Figure 26.19 includes examples that are too general and do not specifically address equity and justice. The Committee suggest including more specific examples.

Figure 26.23 is missing clean water access in this framework. During the winter storms, the water supply system might also get interrupted.

Comments on Equity and Justice

The chapter provides some framing of equity in the introduction, but could benefit from connecting related dimensions (distributional, recognitional, procedural, intergenerational) and their implications for climate justice. The Committee appreciates the historical context provided, attention to the importance of data sharing, and the environmental justice focus of a key message, but urges the chapter authors to look for areas to better integrate equity and justice throughout the chapter. In addition, some perspectives and examples to highlight systemic interconnections would be beneficial. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

This chapter reflects the peer-reviewed scientific literature or other source information cited and incorporates ample recent literature appropriate for NCA5.

CHAPTER 27: NORTHWEST

Summary

Overall, Chapter 27 (Northwest) is thorough, comprehensive, well written, and documented. This chapter does a very good job focusing on the social and economic impacts of climate change to the region. The chapter clearly addresses the requirements of Section 106 of the GCRA. It provides a brief, but thorough evaluation of the climate research specifically focused on the Northwest and clearly identifies the scientific uncertainties associated with the key findings and messages within the chapter.

The key messages are easily identified, generally well stated, and generally supported by the main text. The findings are consistent and supported by timely and transparent research, with the majority of citations since NCA4. Additionally, the Committee appreciates the broad range of resources that are used and referenced. Chapter 27 (Northwest) is written at a technical, yet accessible, level with engaging language that is digestible and of interest to a broad group of audiences as defined in Chapter 2 of this report. An area which might need some extra work is

related to the rather unique regional climate pattern related to ocean dynamics and temperatures, as this region's biological and ecosystems are particularly influenced by the Pacific modulation of precipitation and temperature patterns. An interesting aspect of this region is the atmospheric rivers, which define much of the ecosystem structure and function, and will be influenced by climate change. These systems also influence snowpack and snow melt, setting up a complex set of interactions related to water flow, aquatic habitat impacts, albedo with receding glaciers and snowpack in evergreen forests. At the same time, regional terrain is important to ecosystems and complicate predictions, such as species migration and future ecological dynamics. More specific data related to these aspects and the concomitant complexities inherent in this region would be useful on the climate impacts from changes in these systems.

The Committee commends the many tribal examples throughout the chapter. The focus on tribal nations and Indigenous people is clear and appropriate for the Northwest region and is an important demonstration of significant climate change adaptations and mitigation developments. A notable example is the climate-smart forestry and carbon emission mitigation projects that the Yurok tribal communities have developed. These activities are good examples of carbon financial markets as well.

The "Built Infrastructure" section has the greatest opportunity for improvement. The focus on water, transportation, and energy (Key Message 27.4) could be better linked, perhaps through a brief discussion about state and local climate planning. The urban section struggles to cover a lot of ground given the word count limitations, however, that section could be more focused to better address housing impacts (Key Message 27.4) consistent with the first key message. Specifically, the section should clarify capacity or constraints related to land-use, housing, multijurisdictional planning, and the pace and scale of implementation.

Finally, Chapter 31 (Adaptation) clearly states that progress being made is not sufficient to meet identified climate goals. This chapter does not have the same emphasis on the work that still needs to be done and should identify additional challenges, limitations, or urgency.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction is clear, compelling, and written at an appropriate technical level for broad audiences. Additionally, it provides the context and background on the Northwest region as it relates to climate change; however, the Committee suggests including a brief statement highlighting topics that are not covered in the chapter.

Comments on Key Messages, Supporting Information, and Traceable Accounts

Overall, the key messages in this chapter reflect the current understanding of observed and projected impacts of climate change on the Northwest region, and each key message and associated supporting text appropriately identifies the challenges, opportunities, and success stories with a range of broad to very specific examples and is communicated effectively. The key messages are ordered logically and speak to the issues facing the people who live there. Additionally, the chapter emphasizes the importance of multiple stressors. However, there are

known success stories for activities in this region focused on climate change mitigation, which could be emphasized.

The Committee more specific suggestions below, but as outlined in Chapter 2 of this report, the Committee suggests rephrasing all the key message titles to that they are short, informative statements, thereby making them more effective and impactful. Additionally, the key messages offer confidence intervals, but no likelihood assignments. If there is quantitative data available to support a finding in a key message, there should be a likelihood rating as well as a confidence rating.

Comments on Specific Key Message Language

Key Message 27.1. Frontline Communities and Social Equity

Climate change exacerbates underlying inequities: frontline communities—those now facing the worst impacts of extreme heat, flooding, and wildfires—have often been subjected to discriminatory policies historically (*very high confidence*). Despite such challenges, frontline communities in the Northwest—including urban low-income communities of color, rural and natural resource-dependent communities, and tribes—have shown strong resilience to climate change and legacies of historical and generational trauma (*high confidence*).

Suggested title: “Frontline Communities Disproportionately Affected by Climate Change Often Show Strong Examples of Resilience.”

The statements in this key message are both very high and high confidence but lack specific likelihood language. Likelihood language should be added if there is quantitative evidence to support the statements,

Key Message 27.2. Ecosystems

Ecosystem structure, composition, and function are expected to change as climate variables like temperature and precipitation change and as the magnitude and frequency of extreme climate events increase (*very high confidence*). Historical and ongoing human activities, which reduce ecosystem resilience and the adaptive capacity of some species, are expected to exacerbate many effects of climate change (*very high confidence*). Adaptation actions founded in ecological theory and data are expected to improve ecosystem functions and services and reduce exposure to climate change hazards (*medium confidence*).

Suggested title: “Climate Change Will Reduce Resilience of Ecosystems in Complex Ways.”

The statements in this key message are very high confidence with one medium confidence but lack specific likelihood language. The medium confidence statement references adaptation actions being expected to improve ecosystem function, which is consistent with other confidence levels on adaptation actions but should be addressed more fully whether in this chapter or in Chapter 31 (Adaptation). The Committee suggests coordinating with the authors of Chapter 31 (Adaptation) and cross-referencing accordingly.

Key Message 27.3. Regional Economies and Livelihoods

Climate change impacts to the Northwest's natural resource and outdoor-dependent economies will be variable, given the diversity of industries, landcover, and climatic zones (*very high confidence*). This diversity imparts economic resilience to resource-dependent industries through opportunities for climate adaptation and mitigation (*medium confidence*). Impacts to these industries will have cascading effects on community livelihoods and well-being; however, a just transition can ameliorate some of these impacts (*medium confidence*).

Suggested title: "Climate Change Has Cascading Effects on Job Sectors and Regional Economies."

The assertions in the key message are very high confidence with two medium confidence statements, but they lack specific likelihood language. The medium confidence statements reference the economic resilience of resource dependent industries, and the Committee suggests rephrasing these.

Key Message 27.4. Built Infrastructure

Recent climate-related events have stressed water, housing, transportation, and energy infrastructure across the Northwest (*very high confidence*). Extreme precipitation events, droughts, and heatwaves, intensified by climate change, will continue to threaten these interrelated systems (*very high confidence*). Given the complexity and interconnectedness of infrastructure systems, an impact or a response within one sector can cascade to other sectors (*high confidence*). Cross-sectoral and multisystem planning, which can include reengineering and redesigning aging infrastructure, can increase resilience to future climate variability and extremes (*high confidence*).

Suggested title: "Climate Change Puts Critical Infrastructure at Risk."

The statements in the key message are very high and high confidence but lack specific likelihood language. Additionally, it is unclear if the "very high confidence" rating in the second sentence refers there being extreme events, or that climate change is intensifying them.

Key Message 27.5 Public and Community Health

The Northwest's climate has historically been temperate and relatively mild but shifting weather patterns associated with climate change are adversely affecting physical, mental, and community health (*high confidence*). The incidence of illnesses and death during extreme heat events and wildfire smoke days is increasing, and climate change is compromising health-protective community infrastructure (*high confidence*). Climate related health risks disproportionately affect certain individuals and groups (*very high confidence*). Climate resiliency efforts can be leveraged to improve health, especially among the most vulnerable populations (*high confidence*).

Suggested title: "Climate Change Has Costly Impacts on Public and Community Health."

The statements in the key messages are assigned very high and high confidence but lack specific likelihood language.

Key Message 27.6 Heritage, Sense of Place, and Amenities

Climate change has disrupted sense of place in the Northwest, affecting non-economic amenities like proximity and access to nature and residents' feelings of security and stability (*high confidence*). Place-based communities, including tribes, face additional challenges from climate change because of cultural and economic relationships with their locale (*very high confidence*). Leveraging local or Indigenous knowledge and value systems can spur climate action to ensure local heritage and sense of place persist for future generations (*medium confidence*).

Suggested title: "Climate Change Has Disrupted Sense of Place in the Northwest."

The statements in the key message are very high and high with one medium high confidence but lack specific likelihood language. The Committee appreciates the inclusion of the medium confidence statement related to the leveraging of local or Indigenous knowledges to ensure local heritage and sense of place persist for future generations.

Comments on Text Supporting the Key Messages

Key Message 27.1. Frontline Communities and Social Equity. The Committee appreciates that the first key message in the chapter emphasizes environmental justice, and that there are separate sections on urban, rural, and tribal communities. However, in the section "Climate Action and Social Equity," authors use the term "climate gentrification." Various terms have been used throughout the draft NCA5 report, including "eco-gentrification" and "green gentrification," and as outlined in Chapter 2 of this report, the Committee suggests standardizing terminology across chapters. Additionally, there are notable examples of successful community-based forestry carbon management projects and programs, which would be useful to highlight as existing cases of mitigation that benefit local communities and family forest owners directly. King County is one example, which could be featured by highlighting novel local government activities in carbon financial markets with projects focused on communities and family forests. It was the first local authority to offer carbon credits to local forest managers and demonstrates mitigation and adaptation initiatives already under way. Links to Chapter 7 (Forests) could also be used to highlight work done by tribal communities related to mitigation and adaptation.

Key Message 27.2. Ecosystems. In addition to discussing ecosystems, this key message could also expand its discussion of climate change impacts on natural resources, which are important aspects of the regional economy. There could be more discussion of climate impacts to agriculture and forestry in particular. This discussion could heavily reference what is already written in Chapter 7 (Forests) and Chapter 11 (Agriculture, Food Systems, and Rural Communities) and then focus on specific examples for this region. This discussion should include the impact of invasive insect species, especially regarding climate-mediated migration or dispersal, in the context of forest health. An additional area to consider expanding relates to the discussion of regional climate dynamics. The dynamics of climate change are complex in this region. The warm Pacific currents and the notable atmospheric rivers are discussed, and how this system will respond to climate change presents difficult management and adaptation issues. These complexities are reinforced by SLR, topographic effects, and changes in snowpack and melt water runoff. The response by ecosystems, many of which are economically important, such as forests, is difficult to forecast. Thus, this section could be strengthened with more discussion of the regional climate regime and how it may affect ecosystems under climate change. One way

to describe complexity against a backdrop of natural conditions, climate-change impacts, and land-use pressures would be to expand the example boxes. Box 27.2 could be a basis for this kind of discussion. Figure 27.4 could also be integrated into this box with more elaboration on exactly how climate change exacerbates the effect of other stressors on salmon.

Lastly, although the introduction included an interesting overview of the atmospheric rivers' influence on total winter precipitation, there is very little discussion of how this relates to climate change, if at all. It is sufficiently interesting to the reader that some discussion of it seems warranted in this key message.

Key Message 27.3. Regional Economies and Livelihoods. This key message lays out the importance of natural resources to the regional economy and livelihoods of the people who live there; it benefits the audiences' understanding of the direct importance and impact of climate change by use of economic impact indicators such as crop losses and rising insurance costs. It also considers fisheries and forestry, which is useful for showing diversity of the natural resource-based economy. Box 27.3 is an excellent example of the climate impacts on tribal economies that provides equity and justice perspectives as well. However, the narrative could be expanded here to use examples of successful tribal responses. Tribal communities in the NW region have developed extremely good and notable climate change adaptation and mitigation demonstrations, which could be described, since they provide positive examples of current activities that have been quite successful. A notable example is the climate smart forestry and carbon emission mitigation projects the Yurok tribal communities have developed. These activities demonstrate excellence in carbon financial markets as well.

Key Message 27.4. Built Infrastructure. This section focuses on water, transportation, and energy clearly with challenges, opportunities, and success stories, but is too narrowly focused on infrastructure planning and design without additional discussion on the built environment or planning beyond these identified infrastructure categories. Instead, there should be a discussion on the capacity of local, regional or state entities to plan and implement adaptation and mitigation measures. The Committee suggests that the section on "Urban Areas and Urban Infrastructure" be focused more specifically on housing rather than urban areas and infrastructure. As a topic, urban areas and urban infrastructure is too expansive to adequately be addressed here given word count limitations, and therefore, focusing on housing would be more impactful. The Committee also suggests expanding paragraph 2 of the "Energy Infrastructure" section to include a statement that references Figure 27.8, particularly in relation to transportation electrification, hydropower, and clean energy transition.

Key Message 27.5. Public and Community Health. The Committee commends the authors for providing a good overview of health, from physical to mental to community. Other chapters do not discuss mental health, which is an emerging focal point for discussions on climate change impacts on health issues, so this chapter is outstanding in this regard.

Comments on Traceable Accounts

Generally, traceable accounts for this chapter provide accurate and sufficient context for the embedded content. However, although the traceable accounts are well cited, a number of the "Major Uncertainties and Research Gaps" as well as the "Description of Confidence and Likelihood" sections lack citations. The Committee suggests that the authors make clear what literature is used to specifically distinguish human-cause climate factors from natural factors.

Comments on Graphics and Boxes

Many images and graphics in this chapter were not available for the Committee to review, which makes them difficult to evaluate. The captions, however, are clear and robust, so hopefully the images and graphics match the descriptions well. The charts and maps are clear.

The graphics and tables in this chapter are effective and appropriate, however, they could be better integrated into the text overall. The Committee suggests separating Table 27.1 into two tables (i.e., Tables 27.1 and 27.2). Additionally, the sea-level projections shown in Table 27.1 use neither IPCC nor Sweet et al. (2022) projections; sea-level projections should be presented consistently throughout NCA5 as described in Chapter 2 of this report.

The chapter's use of boxes for examples is good but note that there is no Box 27.1. The box examples could be used to demonstrate the complexity of climate change in this region, for example, the interactions of climate and land-use change, atmospheric rivers, topography, and other factors.

Comments on Equity and Justice

Equity and justice principles are adequately incorporated. Environmental justice, tribal nations and Indigenous challenges, opportunities, and success stories are integrated throughout the chapter. The authors have offered a strong depiction of vulnerable communities as well as their historical and systemic connections. The consistent integration of equity and justice issues throughout the chapter warrants stronger framing in the introduction. Where the different dimensions of equity are described, they should be named. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Data and Analyses

The data shown in figures are clear, credible, and applied appropriately.

Comments on Literature Cited

This chapter appropriately reflects the knowledge base and does incorporate ample recent literature appropriate for NCA5.

Other Recommended Changes

The chapter mentions potential federal-tribal partnerships a few times (e.g., Box 27.3, Key Message 27.6). The Committee suggests adding an example(s) of successful, impactful partnerships.

CHAPTER 28: SOUTHWEST

Summary

This chapter meets the requirements of Section 106 of the GCRA, except for its lack of focus on conditions 25 to 100 years from now, similar to other chapters. The key messages are well written and supported by the details provided in the chapter or by other chapters. The documentation of the key findings is well written at levels mostly appropriate for the intended audiences. More coordination with, and reference to, other chapters is needed in cases where other chapters address some of the issues discussed here in greater detail or from broader perspectives.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction is structured as an introduction to the region and to the variety of challenges and (some) opportunities in the region. As such, it helps to motivate and provide a foundation for the chapter. The final two paragraphs provide an overview of climate change (and adaptation efforts) in the region, which is useful, but care should be taken so that this discussion sets up, rather than attempts to provide a summary of, the chapter's contents. It would be more helpful if these paragraphs were less summary material and more explicitly structured to introduce and prepare the readers for what the remainder of this chapter will focus on and how it will be structured, and then let the remaining text do its job.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The five key messages address water scarcity; the coastline and coastal ecosystems; impacts on agriculture from heat and drought; impacts of heat and wildfire smoke on human health especially in vulnerable populations; and wildfire impacts on ecosystems, people and water. These key messages capture the high-priority issues for the region and are ordered in a logical way (water is at the heart of everything in the Southwest). The supporting discussions are lengthy and occasionally technically dense; they could be broken up with additions of topical subsection titles, as in some other chapters. Key message titles should be written as short, informative statements rather than phrases, and suggested alternative titles are provided below.

Comments on Specific Key Message Language

Key Message 28.1. Water Resources

Climate change has reduced surface water and groundwater availability for people and nature in the Southwest (*very high confidence*), and there are inequities in how these impacts are experienced (*high confidence*). Higher temperatures have intensified drought (*high confidence*) and will lead to a more arid future (*likely*); without adaptation, these changes will further stress existing water supply–demand imbalances (*very likely*). Flexible and adaptive approaches to water management have the potential to address

changing risks, mitigating impacts on people, the environment, and the economy (*medium confidence*).

Suggested title: “Water Availability in the Southwest Is Declining with More Declines to Come.”

This key message provides a quick outline of climate change challenges to the region’s water resources. As short as it is, the listing of challenges and linkages is generally good.

Key Message 28.2. The Coast

Large-scale marine heatwaves and harmful algal blooms have caused profound and cascading impacts on marine coastal ecosystems and economies (*high confidence*). Without implementation of adaptation or emissions reductions measures, human-caused warming will drive marine heatwave temperatures even higher (*very high confidence, very likely*), amplifying negative coastal effects (*medium confidence*). Sea level rise, along with associated impacts such as flooding and saltwater intrusion, is *likely* to have severe and disproportionate effects on infrastructure, communities, and natural resources (*very high confidence*). California state government has applied climate science to planning and decision-making for sea level rise, and multiple regions are moving toward climate-informed and adaptive strategies for fisheries (*high confidence*); however, climate planning and adaptation solutions for aquaculture are less clear (*high confidence*).

Suggested title: “The Coast Is Being Impacted by Rising Ocean Temperatures, Acidity, and Sea Levels.”

Although a lot of information is packed into this key message, it is well written and mostly at a level appropriate to the audiences. Nonetheless, references to Chapter 10 (Oceans and Marine Resources) could be used to reduce the length and technical density here, to focus this section on Southwest specific issues. The key message is well supported and makes good use of confidence statements. However, some statements describe historical and current conditions and others describe future projections, so confidence and likelihood labeling might both be needed, and could help to signal which claim is better. This key message (and supporting discussion) focuses on warming ocean waters and acidification initially, and then turns to SLR. Notably, this key message mentions mitigation. The negative impacts of marine heat waves and harmful algal blooms on fisheries are emphasized. SLR will disproportionately affect poor people in affordable housing in the region.

Key Message 28.3. Food and Agriculture

Continuing drought and water scarcity will make it more difficult to raise food and fiber in the Southwest (*high confidence*). Extreme heat events will increase animal stress and reduce crop quality and yield, thereby resulting in widespread economic impacts (*likely, high confidence*). Because people in the Southwest have adapted to drought impacts for millennia, incorporating Indigenous knowledge with technological innovation can offer solutions to protect food security and sovereignty (*medium confidence*).

Suggested title: “Food, Fiber, and Agricultural Production in the Southwest Are Becoming More Difficult.”

This key message is simple and clear. Both descriptions of high confidence in this key message are not necessarily supported in general, but a caveat like “without major adaptation or new methods and strategies” would help justify the confidence levels given. This key message (and supporting discussion) does not treat forestry as a form of agriculture, although upon reading just the key message, it seemed like “fiber” might include wood. This is not unusual, but the chapter authors could consider making an exception to include forestry in this section because climate change threatens the region’s forests and wood industry in ways not handled under Key Message 28.5 alone. This key message would be an appropriate place to inject some of those other forestry issues (e.g., bark beetles and loss of productivity) that also will plague “agriculture proper” without adding many words. Other chapters could be cross-referenced (e.g., Chapter 7 [Forests]) so there would only be a need to briefly mention specific forestry impacts in this region. This key message does not consider urban water supplies and vegetation much, which motivates the need to retain (and minimally expand) the discussion of urban water supplies under Key Message 28.1.

Key Message 28.4. Demographics and Human Health

Increases in extreme heat, drought, and wildfire activity are negatively impacting the physical health of Southwest residents (*high confidence*). Climate change is also shaping the demographics of the region by spurring the migration of people, primarily from Central America to the Southwest (*medium confidence*). Individuals particularly vulnerable to increasing climate change impacts include the elderly, outdoor workers, and people with low income (*high confidence*). Local, state, and federal adaptation initiatives are working to respond to these climatic and demographic changes and help people and communities become more resilient (*medium confidence*).

Suggested title: “Personal and Population Health Are Adversely Impacted in Many Areas by Climate Change.”

This is a reasonably well written description of the human health costs of climate change in the Southwest. Climate change is one of several factors driving immigration to the region from Central America. These immigrants can add to vulnerable populations (i.e., poor, outdoor workers). Health impacts include air pollution from wildfires (i.e., PM_{2.5}), extreme heat, high ozone, and dust, causing acute and chronic illness with very high costs. As written, this key message is ordered as “Human health and demographics” rather than as titled, “Demographics and human health.”

Key Message 28.5. Wildfire

In recent years, the Southwest has experienced unprecedented wildfire events, driven in part by climate change (*high confidence*). Fires in the region have become larger and more intense (*high confidence*). High-severity wildfires are expected to continue in coming years, placing the people, economies, ecosystems, and water resources of the region at considerable risk (*very likely, high confidence*). Opportunities for adaptation include both pre- and post-fire actions that reduce wildfire risk and facilitate ecosystem restoration, including supporting the application of Indigenous cultural fire and other traditional land stewardship practices (*medium confidence*).

Suggested title: “Wildfire in the Southwest Is Increasing in Size and Intensity Due in Part to Climate Change.”

This key message is well written, at an appropriate level, and the most densely packed overview in this chapter. The key message (and supporting materials) is restricted entirely to wildfires in forests, despite the fact that far more of the region, more of the wildland-urban interface, and more of the region’s wildfire occurs in chaparral, sagebrush steppe, shrubland, grassland and savanna, and other landscapes (e.g., Westerling et al., 2003). This missing perspective is problematic because at least some of the generalizations and statements apply to woodland forests but not to the other settings. Much of this content could be drawn in by more allusions to Chapters 7 (Forests) and 8 (Ecosystems, Ecosystem Services, and Biodiversity) with little addition to this chapter’s length. Although the key message highlights Indigenous practices, the discussion is notably lacking in discussion of that topic.

Comments on Text Supporting the Key Messages

Key Message 28.1. Water Resources. Direct citations of (and more coordination with) Chapter 4 is needed, given the necessary brevity of the discussion here, but no such citations appear in the present draft. The supporting text begins with a description of current megadrought conditions over the Southwest but is implicitly a description of the Colorado River basin. The Colorado River was already in trouble, now it is in big trouble. This issue appears prominently in the supporting materials for this key message but should not be treated as “representative” of what is happening in the region as a whole without explicitly supporting citations or qualifications. In other words, brief additional mention of megadrought conditions in other parts of the region would be helpful.

This initial paragraph, along with Box 28.2 (which appears to be misnumbered—there is no Box 28.1), appropriately focused attention on the recent and ongoing water shortage on the Colorado River. This problem has come to the fore in the past several years, following streamflow declines that have spanned the past two decades and brought the river’s reservoirs to the brink of disaster. The box strictly avoids direct mention of climate change, which is a problem, leaving that issue to the beginning of Key Message 28.1 (page 28-5, line 28), where the causes of the drought are only partially laid out. In other words, the impacts of warming on this megadrought are summarized, but the contributions of long-term precipitation deficits are sidestepped. The assertion that water supplies have been reduced by climate change already is well supported in the literature (e.g., Gangopadhyay et al. [2022], and references therein), but failure to mention that not all the current drought is confidently ascribed to warming is likely to mislead readers. The paleorecord (not mentioned here, but implied in Key Message 4.5, Figure 4.19, though not cited or discussed in this chapter) indicates clearly that long-term precipitation deficits like the one contributing to the current megadrought have happened naturally in the past. Beyond that, current projections of future precipitation are for more precipitation (Figure 4.2) across the northern half of the region, including the Upper Colorado River basin, so that attributing recent, prolonged precipitation deficits to climate change would be hard to justify. Thus, although the current “megadrought” in the Colorado River Basin bears the signature of climate change, in that warming and an associated increase in evaporative demand and evapotranspiration (as a fraction of precipitation) is larger than historical norms, this is one part of the cause of the drought. This is a climate-change-enhanced drought, or a hot drought as in Williams et al. (2020, 2022). However, any reader who is not well acquainted with the large

paleoclimate literature regarding past droughts in the Colorado Basin is likely to interpret the discussion here and later in this chapter as attributing the entire drought to climate change, and that is misleading.

One way to link climate change and impacts in the Colorado River basin into ongoing adaptation would be to mention that, as of summer 2021, the US Bureau of Reclamation has adjusted some of its probabilistic outlooks for major Colorado River reservoir conditions to explicitly explore the drier conditions of the past several decades rather than relying entirely on the full range 20th century climatic conditions for its probabilities.

The key message discussion appropriately emphasizes that snowmelt is important and will be earlier, leading to flooding and decreased water resource availability for energy and water use. The paragraph discussing groundwater impacts (especially related to levels of confidence) should be sure to coordinate directly with the discussion in Chapter 4 (Water). Flooding in the Southwest is caused by both extreme precipitation (mentioned here) and by extreme snowmelt conditions (not included in the paragraph on flooding on page 28-7, line 18), including winter storms that are increasingly rainfall rather than snowfall-dominated and rain-on-snow events. More importantly, the strong emphasis on drought in this key message leads to too little attention to flood issues. A single paragraph mentions the flood threat in the Southwest, and only explicitly describes future increases in terms of atmospheric-river storms. Intensifying atmospheric rivers are of particular importance to future Southwestern water supplies, hydrologic hazards (e.g., floods), and even wildfires later in the year (e.g., Albano et al., 2020; Westerling et al., 2003). This section should explicitly make the connection between increased atmospheric rivers (and other storm) intensities and increased floods, flood risks, and other risks and benefit (Huang and Swain, 2022). The section should also briefly outline the fact that preparations for, and recoveries from, floods are expensive and difficult, and will challenge many existing infrastructures of all kinds (e.g., not just water infrastructure as many examples from the winter of 2023 now show). The chapter appropriately discusses how drought will intensify in the Southwest, but an even more important; however, the chapter should also emphasize that both droughts and floods are expected to intensify, leading a future that is fraught with both extremes.

The key message discussion ends with a listing of examples of adaptation approaches that have been implemented and planned around the region. This list notably does not include explicitly nature-based approaches, and is mostly drought oriented, ignoring challenges to water quality and from flooding.

Key Message 28.2. The Coast. The level of detail and diversity of impacts and some adaptation strategies described is impressive in such a brief section, although some of the terminology used (in interests of concision) is highly technical and not self-explanatory. It might be worth noting that usage of the term “marine heat wave” is a recent development in the literature and especially in the public view, which gives some suggestion as to how quickly coastal and oceanic conditions are being observed to change (as recently as 2015, the common usage in both the media and scientific meetings was “The Blob”). Nature-based solutions are included along with the hard-engineering options in this key message. Reference to other chapters, that have more space to address these coastal issues (e.g., Chapters 9 [Coastal Effects], 10 [Oceans and Marine Resources]) is lacking and might help to free up space for even more discussion of adaptation and specific impacts.

Key Message 28.3. Food and Agriculture. In California’s Central Valley (Figure 28.6 and related discussions) and in other important riverside agricultural settings elsewhere in the region, flooding of agricultural lands is likely to be an increasing risk, but both here and in Key

Message 28.1, most attention and verbiage is focused on droughts. The Southwest is projected to increase the occurrences of both extended droughts and occasional but extreme floods, and this discussion should reflect that complexity.

On page 28-17, the characterization of problems at the Salton Sea due to competition between urban and agricultural water demands is incomplete and problematic. The Salton Sea is declining—to the extent that urban demands are playing a role—because historical inefficiencies in (and leakage from) agricultural water conveyances and irrigation methods are being reduced, to free water for urban uses, but they were water delivery and application inefficiencies corrected, not supplies taken away. Thus, challenges facing the Salton Sea are not the best example of competing urban and agricultural water demands; rather, the challenges illustrate a possible maladaptive outcome from efforts that limit water supplies farther. In other words, the Salton Sea is not as direct an urban-rural water competition as, for example, the Owens Valley or competition between Phoenix and agricultural developments in Arizona (Karimi, 2023).

Key Message 28.4. Demographics and Human Health. Page 28-22 mentions annual average PM_{2.5}. While this metric is relevant to National Ambient Air Quality Standards, this broad metric may obscure important episodic spikes in PM_{2.5} that are important to note. The text does make the point that average PM_{2.5} was decreasing until the wildfires raged. This point should not obscure the importance of air pollution mitigation actions.

Also on page 28-22, there is an assertion of “a lack of occupational health standard for farmworkers and outdoor workers.” There is no federal heat standard that ensures the safety and health of workers who are exposed to dangerous heat conditions in the workplace, which is a particular concern in the hot, arid climates of the Southwest. California, Minnesota, and Washington, as well as the US military, have adopted their own heat stress standards successfully. The Occupational Safety and Health Administration is working on rulemaking nationally (*Federal Register*, 2021b). This full context should be noted.

Also on page 28-22, line 19-20, it speaks to loss of drinking water sanitation after fires, but experience in California is that more often, there is loss of water supplies for months. In this section, it is also important to identify landslide risks with heavy rain on recent burn areas. It is mentioned in the wildfire section, but it is beginning to amount to a public health hazard.

On page 28-24, it is helpful to mention the Centers for Disease Control and Prevention’s Building Resilience Against Climate Effects program, which is now up to 10 states with small funding allocations, though this is expected to increase under the Inflation Reduction Act. While the program has been small, it has developed methods and strategies that can be scaled up.

Key Message 28.5. Wildfire. The stage-setting literature references (i.e., first paragraphs of the supporting material) tend to be evaluations by climatologists of climate impacts on wildfire risks, rather than literature from the forestry or fire community itself, which may have led to overgeneralizations based on their woodland forest focus. The discussion of this key message should start by pointing out the diversity, and maybe proportions, of wildfires in different types of vegetation (e.g., grassland, shrubland, forests) in the region and that some Southwest ecosystems are fire adapted, and some are not; this statement comes a bit late.

The section on adaptation should acknowledge that strategies of reducing tree density and wildland fuels only pertain to certain forested ecosystems in the west and are noneffective and counterproductive in other ecosystems. There are other strategies to reduce human ignition risk in addition to fuels reductions (which does not even appear in the list on page 28-26, line 29), such as land-use planning and zoning that reduces low density housing in the wildland-urban interface and makes properties fire resistant without extensive and counterproductive clearing of

vegetation. Furthermore, invasive species control will reduce fire risk in desert ecosystems not adapted to fire where invasive grasses have promoted fire in the Southwest region. Finally, the comment that “prescribed fire may be curtailed due to public concerns” (page 28-28, lines 8-9) could be strengthened to emphasize that it is extremely difficult to use prescribed fire at the scale necessary to manage forest fuels and counteract the historical effects of fire suppression because of concerns (and laws) about air quality, human health, and losses of structures and human life.

Very large areas are being impacted by the enhanced wildfires being experienced, especially where multiple fire scars accumulated over the recent decades. This discussion of impacts seems to be focused on what happens within the footprints of individual wildfires, including extremely large footprints recently, but the cumulative footprints are increasingly changing whole drainage basins, watersheds, and landscapes (e.g., Williams et al., 2022). Cumulative area-wide impacts have risen to levels where they require some attention and discussion here.

The discussion of this key message is focused almost entirely on how to reduce wildfire occurrence and property impacts. Another increasing concern, following several recent megafires in the Southwest, is how to reduce human mortality, for example, by requiring new buildings and communities to have appropriate escape routes.

Comments on Traceable Accounts

This chapter has a more complete and consistent use of citations to support the assertions of the traceable accounts than some other draft NCA5 chapters. Among the traceable accounts, the Key Message 28.4 is the best cited and justified and may be a good model for chapter traceable account revisions generally. The traceable account for Key Message 28.5 has the most readable description of confidence levels. However, some additional discussion to justify—rather than just state—the likelihood assignments is warranted, as discussed in Chapter 2 of this report. Furthermore, the key messages mostly offered confidence assignments and very few likelihood assignments, and explanation for how the authors made these assignments is needed.

The traceable accounts for this chapter use citations are inconsistently and the emphasis on particular topics does not sufficiently support statements in the key messages and supporting text. The overall “Process Description” provides good context for understanding the chapter contents. The “Descriptions of Evidence Base” for Key Messages 28.1 and 28.3 (and, to an extent, Key Message 28.2) are notable for their brevity and thus how little they say, which is a problem. Key Message 28.2 “evidence base” is described without a single citation, while the others use and provide citations more sensibly. The “Major Uncertainties and Research Gaps” section for Key Messages 28.1 and 28.5 are sparsely supported by citations, while Key Messages 28.2 and 28.3 use no citations at all; without some literature support there is no foundation (other than personal conjecture) for describing the uncertainties and no basis for judging and describing the gaps.

“Maladaptation” appears once in all the traceable accounts (page 28-30, line 16), but not once in the body of the chapter. This is an important consideration (with respect to all the key messages and their discussions of adaptation strategies) that should not only be introduced in passing in one traceable account.

The discussion on page 28-32, describing how the US average SLR will progress, lacks substance. SLR on the California coast has been progressing more slowly than on the US east coast or even on the other side of the North Pacific (see Chapters 9 [Coastal Effects] and 10

[Oceans and Marine Resources]). Part of this slower change is due to multidecadal North Pacific climate variations that are believed to be natural. Current best understanding is that the natural circulations that have kept rising global water levels away from the west coast, and instead over in the western half of the North Pacific, can be expected to reverse themselves at some point in the future (Bromirski et al., 2011, 2012; Moon et al., 2013). When this happens, the “pent up” SLR Pacific can relax back toward the US west coast so that west coast SLR will tend to catch up (likely rapidly) to the global averages. Thus, US averages of SLR are almost meaningless for the Southwest region. This issue should be included at least briefly in the chapter text and incorporated into considerations in this traceable account. Stated another way, recent SLR and future projections for the Southwest region are nowhere as simple nor certain as this traceable account implies.

Comments on Graphics and Boxes

The figures used here are well done and accessible. Additional infographic-type summaries of processes and risks, such as Figures 28.1 and 28.6, would be valuable for the other key messages, but such syntheses may be hard to come by.

In Figure 28.2a, “reduced soil moisture” (page 28-7, line 2) is in contradiction to what is shown in Figure 28.2a for most places of the Sierra Nevada (as far as this figure extends). When an observed change is in the opposite direction of the projections of future change (see also Figures 4.4 and 4.6), it is important to either avoid attributing the observations to climate change or to provide some specific reasons why the observations are due to climate change despite disagreeing with projected expectations.

In the caption of Figure 28.5 (page 28-13, line 3), “including the Delta” is the only mention in this chapter of this important sea-level risk at the heart of California’s large-scale water-supply conveyance systems. Conveyances between northern and southern California are projected to have highly likely, long-term (~18-month) disruptions when SLR-hastened levee breaks occur; a brief mention of this problem in Key Message 28.2 is needed.

The figures supporting Key Message 28.4 are not viewer friendly. Figure 28.7 conveys important and readily understandable information (heat reduces work capacity, and this will increase with climate heating), but the visual requires close reading of a long, detailed caption.

In Figure 28.8, some more explanation of how this resilience measure is estimated is needed (e.g., which risk factors are considered). A brief mention should be made as to how such factors are “modeled” in the caption or text. Finally, it is worth pointing out that some of the areas of highest risk coincide with Indigenous communities.

Comments on Equity and Justice

The authors provide some framing of equity and justice in the chapter introduction, which could additionally benefit from the integration of related dimensions (distributional, procedural, recognitional, intergenerational equity). The extent to which equity and justice issues are integrated into the key message discussions varies a lot. Only impacts on Indigenous communities are discussed in Key Message 28.1 supporting materials, although the topic is raised in the key message itself. A new citation that could provide a starting point for a broader view of key disparities facing urban populations in the Southwest is Sanders et al. (2023). The impacts of SLR on housing for vulnerable (coastal) populations are discussed for Key Message

28.2, while broader perspectives are addressed in Key Message 28.3. The immigrant demographics, and inequities in human health impacts and access to health services, are addressed in Key Message 28.4. The mention of Indigenous practices in Key Message 28.5 is appropriate, but then little discussed in the supporting text.

The final paragraph in Key Message 28.1 outlines the disproportionate challenges faced by Southwest tribes regarding water resources, but neglects consideration of other equity and justice groups and challenges—for example, access to water supply and quality for people with low income in urban and rural areas. These other disadvantaged groups are discussed explicitly in other key messages.

Key Message 28.5 is notable for mentioning Indigenous practices (in the context of wildfire) prominently, and then hardly mentioning them in the discussion. Given the growing literature specifically about actual and potential uses of traditional knowledge in wildfire management, this is a surprising gap. This could be enhanced by cross-referencing Chapter 7 (Forests), which does address this topic with the example of fire management and climate adaptation led by the Yurok tribe. Some relevant references cited in Chapter 7 (Forests) (e.g., Lake, 2021; Marks-Block et al., 2019) can be included. There may be other relevant discussion in Chapters 8 (Ecosystems, Ecosystem Services, and Biodiversity) or 16 (Tribes and Indigenous Peoples) that can be cross-referenced without adding much additional text to this chapter. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

The literature is generally timely with a focus on new findings since NCA5, and appropriate. It would be useful if, in addition to looking at the dates on the citations, the authors could call out some selected major advancements of the science, data, or understanding since NCA4, either in the introduction or in the text.

On page 28-4, line 37, no references are provided regarding improved modeling of invasive species, biodiversity loss, or ecosystem transformations (the provided references all pertain to fire). At the very least, references to other chapters that do provide more information or detail are needed.

In the discussion of Figure 28.5 or in the discussion of SLR adaptation options (page 28-14, lines 13-24), it would be useful to cite important work by Wang et al. (2018) that describes how differences in seawall and levee (height) adaptations to projected SLR around San Francisco Bay are likely to yield disparate flooding impacts from one community to the next unless coastal infrastructures are adjusted in spatially coherent ways. There is a very important lesson, regarding a basic ground rule for adaptation planning, in this example—do no harm to your neighbors—that is worth capturing here.

CHAPTER 29: ALASKA

Summary

This chapter provides a well-written, comprehensive account of how the state will change and is being impacted by climate change. The chapter meets the requirements of Section 106 of

the GCRA. The authors did an exceptional job crafting the narrative of the chapter and not just listing facts, which made it an interesting and easy chapter to read. The chapter authors also did an excellent job cross-referencing other chapters in the draft NCA5 report. The findings begin with current conditions and then look toward the future, albeit not that far into the future given the rapidity of existing changes. The chapter emphasizes societal implications of climate change for Alaskans' health, communities, livelihoods, built and natural environments, security, and its future. The key findings are well stated and supported by details provided throughout the chapter and traceable accounts. The Committee commends the authors for clearly acknowledging arenas where positive changes have occurred and where real opportunities for improvement will emerge.

The Committee suggests that the authors ensure additional context is provided in some of the examples, so that audiences not familiar with Alaska can understand what is being discussed.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction in this chapter is longer than the introduction in some other chapters, and the NCA5 authors should decide on a consistent format for introduction length (see Chapter 2 of this report). Depending on the decision, the authors may consider segmenting out a section of the introduction and adding another key message. It would be helpful if the introduction provided a very brief discussion of findings in past assessments (i.e., NCA4). The large focus on human systems is useful and warranted, but for a reader who is unfamiliar with Alaska, it will seem like a large portion of the chapter related to the physical science and impacts of climate change on the state is missing. Table 29.1 is a great visual tool for organizing information in the introduction and setting the stage for the rest of the chapter and is a model for other chapters to follow.

Comments on Key Messages, Supporting Information, and Traceable Accounts

This chapter is generally written at an appropriate technical level for broad accessibility. However, the first-person language within the key message titles (i.e., “our” and “we”) is imprecise for the intended audiences. Revising the language could be an opportunity to develop more informational key message titles (see Chapter 2 of this report for further explanation). The key messages could also be strengthened by including more assessments of likelihood. The detailed information provided within the traceable accounts section is appreciated. However, the traceable accounts should be expanded to discuss the evidence base for the likelihood evaluations which are added to the key messages.

Comments on Specific Key Message Language

Each key message begins with “our” which implies belonging to both the author and the reader or only the author and alienating the reader if the reader does not feel that connection. The Committee suggests revising the key message titles to be short, informative statements will be more impactful for broader audiences.

Comments on Text Supporting the Key Messages

Key Message 29.1. Our Health. This section describes how climate change is impacting the health of Alaskans, and how it might affect them in the future. Throughout this section, it would be useful to clarify when the literature reviewed is specific to Alaska versus studies that are generally about climate change and health. The chapter authors are urged to evaluate the contribution of climate change to the described health impacts more carefully. For example, on page 29-10, lines 32-39, it is not explicit how harmful algal blooms (HABs) affect people. Chapter authors should explain how HABs end up food sources and why these food sources are important. In addition, on page 29-11, lines 3-6, it is unclear whether the lack of indoor plumbing was the primary driver of COVID-19 infections. If more than one factor is described in the study, it might be better to frame this as a contributing factor versus a causal relationship.

Key Message 29.2. Our Communities. This section discusses how (current) residents and communities in Alaska will be impacted but neglects the somewhat longer view of how the state will fare as it becomes a more and more attractive climate for living in the future. Consider using more specific language than “communities”—it is not clear what is being referred to (e.g., Alaska Native communities, intersectional lens on people who live in particular ways and affected by particular drivers). This section would be more precise and less ambiguous if there was a brief discussion about how communities were defined and what language is being used to reference Alaska Native communities specifically. Consider discussing whether and how Alaska is planning for “climate gentrification” and a climate-driven in-migration, which may occur in the future, if evidence is available.

Key Message 29.3. Our Livelihoods. This section read as unbalanced. Figure 29.7 lays out five main economic impacts of climate change on the state, yet two long paragraphs are about fisheries, two short paragraphs are about subsistence, and one paragraph is a catch all. This section could be strengthened by cutting back the discussion about fisheries and including more discussion about the other economic sectors that correspond with each part of Figure 29.7.

Key Message 29.4. Our Built Environment. Overall, this section is well written. Like other sections, it could be more precise with further discussion of what is intended by the word communities. The chapter authors may also consider briefly mentioning the legal and governance challenges related to relocation, in that no one entity is legally responsible to pay for these relocations.

Key Message 29.5. Our Natural Environment. This is generally a well written section. However, it could be strengthened with more references or concrete examples to support the discussion about increasing conflicts over fish and wildlife resources (page 29-25, lines 14-18).

Key Message 29.6. Our Security. Consider expanding the focus of this key message to “safety and security” or define security. As written with a focus on national security, it is confusing to have the Alaska native security also included in this section. Clear definitions could make this section more coherent, despite the different types of security being discussed.

Key Message 29.7. Our Future. This is a very well written section. However, chapter authors may consider briefly mentioning or citing a reference that describes the Alaska Native Claims Settlement Act and the unique tribal governance structure in Alaska. Chapter authors may also wish to expand the discussion about how this complicated governance structure makes climate change decision making more difficult, and even leads to conflicting goals between the corporations and the regional organizations. This section also could be strengthened with an expanded discussion of climate change mitigation activities in the state.

Comments on Traceable Accounts

The traceable accounts for this chapter are generally short and lack references and should be expanded to explain the supporting evidence for each key message. The discussion of how chapter authors determined confidence and likelihood for each key message should also be expanded on.

In the traceable account for Key Message 29.1, the Committee appreciates the inclusion of climate-induced mental health impacts and responses. The chapter authors appropriately note the dearth of studies looking at climate-related mental or emotional health. Therefore, the Committee suggests avoiding the generalization of impacts reported from a few papers from one study in eastern Canada with First Peoples to all Indigenous peoples and Alaska Natives. Suggested edits are noted in Appendix A.

Comments on Graphics and Boxes

The Committee appreciated the effective tables, figures, and boxes in this chapter. Most captions are very well written and include an appropriate amount of detail and references back to the source material. The Committee suggests that all captions have citations back to the source material if they are summarizing the state of the knowledge. The Committee suggests that all maps have scales and key labels. Because many readers may be unfamiliar with the locations discussed throughout the chapter and the nature of Alaska's geography and infrastructure, the authors may consider adding a summary map in the introduction with places called out throughout the chapter identified.

Table 29.1 serves as an introductory executive summary of the chapter and could be a template for the introduction of other chapters.

Regarding Figure 29.2, at the point in the chapter this figure is introduced, it seems odd that these examples are dropped in here. The Committee suggests providing more context and designing the examples to have a similar look and feel to each other. The Denali Park Road figure looks like there is a rock on the road and it does a poor job characterizing the problem. The figure suggests that rocks block the road to the lodges, but that is not really the nature of the problem.

Figure 29.8 could be reassessed as to whether it best represents the authors' intended message of importing seafood into a fishing village. Additional comments are provided in Appendix A.

The authors make a good use of boxes to share examples and firsthand accounts throughout the chapter. The boxes are nice vignettes, but the authors should consider providing some additional detail to the boxes to be more effective stand-alone stories. For each box, include some additional context about the place or ecosystem being referenced (i.e., Kotzebue is a community of X people, located X), the quotations (i.e., where is this person, who is this person, how do they interact in these spaces), and impacts (i.e., sea/river ice trends that make travel more dangerous) so that readers can better understand the vignette. Consider pairing the quotes with some data or a graph to add this context. Some of the best boxes in the draft NCA5 report include firsthand accounts, research, and climate trend information presented together.

Box 29.1 is a good inset box but could be expanded on. The firsthand account would be more meaningful for audiences if chapter authors provided context about this region, the people, and local conditions. For example, a figure with sea ice trends for the region or more information

about how residents have to go on the ice to gather food would help readers better understand the firsthand account.

Box 29.2 could be much more impactful if chapter authors put the fact “snow and cold are expected, rain is not” into context with some data to further show how this was an unusual event. Authors may also consider expanding on how the community was not equipped to respond to these conditions, with power outages for days, lack of road work, etc.

Box 29.6 is thin in context. The Committee suggests adding more information, such as a brief discussion about tribal sovereignty, or further contextualizing the examples. The Knik example could be strengthened by mentioning how much land is in cultivation and how many other people are being fed.

Comments on Equity and Justice

In general, this chapter does a good job applying an equity and justice lens with respect to Alaska Native people. Although the authors mention the other kinds of racial/ethnic diversity in the state and the data are limited, there is not much discussion on how climate change will affect people overburdened due to other races or other factors. This discussion could be expanded on. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

Additional references are needed throughout this chapter any time a claim is made. There are especially limited references with respect to some descriptions of climate impacts, cryosphere processes and change and as a physical driver for many impacts on society. For example, on page 29-4, lines 26-29, and page 29-5, lines 10-14, a series of trends in climate impacts is mentioned but not referenced. Key Message 29.1 should reference Dannenberg et al. (2019).

Other Recommended Changes

Adaptation and mitigation seem to be interchangeable in some instances. Mitigation is generally underappreciated throughout the draft NCA5 report, as discussed in Chapter 2 of this report. In addition, the implications of a changing climate on the fossil fuel industry and economy of Alaska are not addressed. Authors should consider addressing what is known about trends in fossil fuel development as it may be impacted by changes in policy and regulation intended to limit GHG emissions, and subsequent ripple effects or instabilities on the state’s economy.

In addition, this chapter would benefit from more precise language when describing climate change, natural variability, and the impact of other drivers. Similarly, the chapter authors should be precise when talking about Alaska Native communities versus the use of communities as an encompassing term. Chapter authors should also be mindful that there is an overall balance between discussions about marine and terrestrial ecosystems. As written, marine ecosystems are well described and referenced with concrete examples, whereas terrestrial ecosystems could be emphasized more.

CHAPTER 30: HAWAI‘I AND US-AFFILIATED PACIFIC ISLANDS

Summary

The Hawai‘i and US-Affiliated Pacific Islands (USAPI) chapter satisfies Section 106 of the GCRA and provides effective key messages that are relevant for the target audiences with a particular emphasis on the power and success of adaptation strategies rooted in traditional and Indigenous knowledges. The chapter also emphasizes equity and justice throughout by highlighting groups that are disproportionately affected by climate change, particularly as it pertains to mental and physical health. The supporting content for the key messages is well written and contains references to a substantial body of recent literature. Areas for improvement include the lack of connection to the physical-science basis both within the chapter and across the draft NCA5 report; inaccurate links between SLR scenarios and IPCC emissions scenarios; and unclear or insufficient descriptions of confidence likelihood in the traceable accounts.

The Committee notes that Chapter 1 (Overview) mentions Hawai‘i only a handful of times and the USAPI only once in a table. Chapter 1 (Overview) (as well as other physical-science basis and national chapters) should be more inclusive of Hawai‘i, and especially the USAPI.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The first section of the introduction provides a brief yet adequate and well-written overview of the chapter.

The second section of the introduction provides the physical-science context for the chapter, which could be improved in a variety of ways. First, there is no connection to Chapters 2 (Climate Trends) or 3 (Earth System Processes), which provide the physical-science basis for the draft NCA5 report. Better utilization of these chapters would add additional context for this chapter by examining a wider range of climate trends and systems beyond precipitation and sea-level. The Committee notes, however, that these chapters do not adequately provide information for Hawai‘i and USAPI in many cases. The Committee outlines a recommendation in Chapter 2 of this report for those chapters and the draft NCA5 report overall to provide climate information equitably across all regions and territories, including for Hawai‘i and USAPI. The Committee encourages the chapter authors to incorporate this recommendation by leveraging and referencing the recommended additions to the physical-science basis chapters that will cover Hawai‘i and USAPI.

Second, there are few mentions of natural climate variability (e.g., Pacific Decadal Oscillation [PDO], El Niño–Southern Oscillation [ENSO]) and other non-climatic physical processes (e.g., changes in tides, vertical land motion) and their interactions with climate trends. ENSO is mentioned in the last sentence of the first section of the introduction, which elevates its importance and gives the expectation that this feature of climate variability—which is indeed critical for Hawai‘i and US-Affiliated Pacific Islands—will be robustly discussed throughout the chapter. However, ENSO is not mentioned again until the traceable accounts section of Key Message 30.1 (page 30-36, lines 8-11), and this is the only other place it is discussed. It is

recommended that the content related to ENSO be moved to the introduction due to its importance and then referenced throughout the chapter. Another relevant example of the importance of natural variability is the high rates of SLR in the western Pacific, which are not due to climate change alone, but rather a combination of climate change and natural fluctuations in the PDO. The authors cite Merrifield and Maltrud (2011) regarding western Pacific sea-level trends, but there are more recent papers that highlight the relationship between these trends and the PDO (e.g., Merrifield and Thompson, 2018; Merrifield et al., 2012). This is essential context because scientists do not expect the trends in the western Pacific to continue unabated but rather to wax and wane over time with the PDO. Beyond climate variability, there is also subsidence in American Samoa (Han et al., 2019) that greatly exacerbates climate-related sea-level trends and is currently contributing to severe impacts on water resources and flooding in the territory. There is also no mention of the interaction of sea-level and variation in tides on decadal timescales that can alternately suppress or amplify the impacts of climate-driven SLR on the frequency of tidal flooding (Thompson et al., 2019, 2021). This is particularly important in Hawai‘i, where the interaction between tides and sea-level is expected to produce a rapid increase in the frequency of tidal flooding during the mid-2030s. There are likely other examples as well regarding variables other than sea-level, but in summary, it is essential that the target audiences of NCA5 (i.e., decision makers) understand that (a) not all trends are solely due to climate change, and (b) non-climatic trends and variability can both mitigate and exacerbate the impacts of climate change—sometimes alternating from one decade to the next—and these effects are important to consider in planning efforts.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The key messages of this chapter are generally well written and useful for the target audiences, and they are organized into logical and distinct sectors. The supporting text and traceable accounts for the key messages contain many relevant and recent citations, demonstrating a thorough review of the recent literature on climate-driven impacts to the region. There are, however, general and specific ways in which the key messages can be improved. The discussion below addresses issues that span multiple key messages, followed by comments specific to existing content in individual key messages.

The titles of all key messages should be formulated as brief, informative statements rather than categories of information. For example, the current title for Key Message 30.1 is “Water and Food,” which should be recast as a statement such as “Climate change impairs access to water and food.” The title for Key Message 30.2 could be recast as “Climate change undermines human health; community strength boosts resilience” (or perhaps a version of that with fewer words).

There is little connection to the physical-science basis provided in the introduction throughout the key messages and their supporting text. Figures 30.2 and 30.3 describe trends in precipitation and sea-level but are never referenced outside the introduction. In general, the context provided by the introduction regarding the physical climate system needs to be woven throughout the key messages and connected to the statements and conclusions made.

Similarly, the Hawai‘i and US-Affiliated Pacific Islands chapter is largely siloed within the draft NCA5 report overall. The only other chapter cited within the Hawai‘i and US-Affiliated Pacific Islands chapter is Chapter 15 (Human Health). Otherwise, there is no attempt to connect with the wealth of material outside this chapter. The Committee suggests the chapter authors

identify ways to leverage the physical-science basis and information on human systems detailed elsewhere in the draft NCA5 report, including Chapter 16 (Tribes and Indigenous Peoples), which connects with the focus in this chapter on traditional and Indigenous ways of knowing and the role this knowledge plays in adaptation efforts.

Comments on Specific Key Message Language

Key Message 30.3. Built Environment, Livelihoods, and Economy

Climate change, particularly sea level rise, is damaging and will increasingly negatively impact buildings, infrastructure, and other elements of the built environment (*very likely, high confidence*) and will harm numerous sectors of the islands' economies (*very likely, high confidence*). Climate-driven changes will exacerbate existing social challenges—disrupting livelihoods (*likely, medium confidence*), reshaping existing human migration patterns (*likely, medium confidence*), and intensifying displacement (*very likely, high confidence*). Government and community groups have developed innovative ways to mitigate emissions and improve resilience by moving toward green infrastructure, nature-based urban planning, forward-looking building codes, and sustainable and equitable economic growth, ideally all guided by the best available science and traditional knowledge.

The chapter authors should be careful about using the word “will” when the likelihood is not *virtually certain*, because “will” implies certainty. Instead, the authors could use the NCA5 confidence/likelihood language within the sentence instead of in a parenthetical at the end of the sentence. For example, the first sentence could state, “Climate change, particularly sea-level rise, is *very likely* to increasingly negatively impact buildings....”

The phrase “increasingly negatively impact” is awkward. Perhaps the authors could shorten the phrase to just “increasingly impact” as the context implies the impacts will be negative, or “increasingly harm” which avoids any ambiguity about the valence of the impact.

Key Message 30.4. Ecosystems and Biodiversity

The structure and composition of Pacific Island coastal and marine ecological communities are directly threatened by rising ocean temperatures, ocean acidification, and sea level rise (*highly likely, high confidence*). Increasingly severe droughts and warming are increasing fire risk (*high confidence*) and will have broad negative impacts on native plants and wildlife, including an increased risk of forest bird extinctions (*very likely, high confidence*). Strategies to improve the resilience of Pacific Island ecosystems to climate change include ecological restoration and invasive species control (*medium confidence*), investments in fire prevention (*high confidence*), better stewardship of freshwater resources (*high confidence*), and avian malaria control (*high confidence*).

This key message uses the term *highly likely*, which is not part of the NCA5 confidence/likelihood language. The specific attributes, trends, and threats to US Pacific ecosystems, including the potential for effective adaptation through partnership with Indigenous knowledge holders, has strong parallels with Chapter 23 (US Caribbean), and the chapters could benefit from cross-referencing each other. Also, the interaction between climate change and other stressors (e.g., invasive species, novel fire regimes, land-use change) is the basis of Chapter

8 (Ecosystems, Ecosystem Services, and Biodiversity), and this key message should reference that chapter and perhaps seek to use similar terminology where relevant.

Comments on Text Supporting the Key Messages

Regarding the text supporting Key Message 30.3, as mentioned above, authors should provide likelihood rankings for the statements regarding SLR occurring as early as 2075. The Intermediate High scenario from the US Interagency Task Force (ITF) report (i.e., Sweet et al., 2022) does indeed correspond to the amounts of SLR by 2075 stated in the chapter. However, this scenario has a low probability of occurring within the IPCC emissions-based framework used throughout the draft NCA5 report. A helpful table in the ITF report is Table 2.4, which relates (albeit in an indirect way) the IPCC emissions scenarios and the ITF SLR scenarios. The second-to-last row shows the probability of the Intermediate High scenario given various levels of warming and the closest IPCC emissions scenarios in the top two rows, respectively. For the ITF Intermediate High scenario, there are very low probabilities of this scenario occurring for even high-end warming outcomes (i.e., 2% for 5°C of global warming by 2100). Only in the very last column corresponding to Very High emissions (SSP5-8.5) and including low-confidence processes such as marine ice-cliff instability is there a substantial probability of the ITF Intermediate High scenario occurring—and even then, the probability is only 20 percent. To be clear, the use of the ITF Intermediate High scenario itself is not being criticized—the ITF scenarios are useful tools—but it is essential to provide proper context for the ITF scenarios in terms of the emissions scenarios and processes they represent. For example, the parenthetical on page 30-20, line 35, currently says, “under an intermediate–high SLR scenario; Sweet et al. 2022.” This should be revised to reflect NCA5 language for likelihood (Front Matter, Table 2), noting that the probability of the ITF Intermediate High scenario is near the upper bound of the *likely* range for Very High emissions (Front Matter, Table 3) when including the possibility for marine ice cliffs to become unstable due to processes for which there is low confidence in projections. One possibility is to change the parenthetical referenced above to be “under an intermediate–high SLR scenario that is physically plausible but *unlikely* under Very High emissions when including low-confidence processes; Sweet et al. 2022.” Alternatively, the authors could use a lower scenario such as Intermediate, which is *as likely as not* to occur under Very High emissions when including low-confidence ice-sheet processes, but then the statements regarding amounts of SLR by 2075 should be altered. These issues also apply for other statements in this key message regarding SLR.

The Committee has no major concerns regarding Key Message 30.5, but the supporting text would benefit from cross-referencing other NCA5 chapters such as Chapters 16 (Tribes and Indigenous Peoples), 19 (Economics), and 23 (US Caribbean).

Comments on Traceable Accounts

The purpose of the traceable accounts is to directly support the key messages. Thus, the “Descriptions of Confidence and Likelihood” should support and provide the rationale behind the specific statements of confidence and likelihood made in the key messages. However, there is a general disconnect across all key messages in the Hawai‘i and US-Affiliated Pacific Islands chapter between the statements made in the key messages and the “Descriptions of Confidence and Likelihood” in the traceable accounts sections. For example, Key Message 30.3 attributes

both confidence likelihood levels to five statements. In the “Descriptions of Confidence and Likelihood” for Key Message 30.3, there is discussion of only one confidence statement and one likelihood statement, and the rationale provided for these statements is inadequate. The chapter authors should provide one-to-one descriptions for *how* they assess confidence and likelihood for each statement made in each key message, particularly when making likelihood statements for which the NCA5 language corresponds to specific probability ranges. The authors should describe how the probability assessments were made and under what conditions they are applicable. For example, when a predictive statement is *virtually certain*, the chapter authors should state whether this applies across all possible futures for society in terms of emissions or if it is only *virtually certain* under higher emissions scenarios (i.e., SSP3-7.0 and SSP5-8.5).

Along similar lines, the application of confidence versus likelihood statements throughout the key messages is inconsistent with the intended usage outlined in the Front Matter on page 0-9. Confidence is intended to be a *qualitative* statement based on the amount and consistency of information available. Likelihood is intended to be a *quantitative* statement based on observations and model projections or an assessment of such *quantitative* information across sources. It is often unclear whether the authors distinguish between the qualitative versus quantitative natures of the two types of assessments. For example, Key Message 30.3 states that it is *likely* that climate-driven changes will disrupt livelihoods, which, according to NCA5 confidence/likelihood language, corresponds to probability greater than 66 percent. The traceable account needs to explain how this probability is assessed, whether there are specific models that predict livelihood disruption based on climate trends, and how the likelihood of greater or lesser climate trends gets folded into the likelihood of livelihood disruption. These are the types of details necessary to support likelihood statements in the traceable accounts. Otherwise, the authors can use confidence statements to make statements that are generally agreed upon but not quantitative in nature.

Key Message 30.1. Water and Food. The purpose of the traceable accounts section is not to introduce new concepts and topics, but rather to provide supporting documentation for content already discussed in the key message and its supporting text. The content in the traceable account for Key Message 30.1 focused on ENSO (page 30-36, lines 8-11) does not conform to this guideline, as it introduces a new topic not discussed in detail elsewhere. In addition, the content related to ENSO is highly important for the region and should be elevated to the main text where it can be read by broad audiences. The Committee suggests that this content be moved to the introduction section with other aspects of the physical-science basis for the chapter and then referenced throughout the key messages.

The “Major Uncertainties and Gaps” section for this traceable account should include the lack of island-specific groundwater models throughout the Pacific region.

Key Message 30.3. Built Environment, Livelihoods, and Economy. The “Major Uncertainties and Gaps” section should include that the lack of high-resolution topobathymetric information for many Pacific Islands is an important barrier to generating accurate wave run-up models for the region. There is also a lot of uncertainty in the amount of SLR that will be experienced across the region due to the potential for instabilities in marine ice cliffs for which scientists have low confidence in their ability to represent these processes accurately in models (see Chapter 3 [Earth System Processes], page 3-26, for more information).

Comments on Graphics and Boxes

Eight of the chapter's 15 figures contain only photographs, which can be helpful in providing context and sense of place, but photographs do not help the target audiences understand and synthesize the wealth of information provided in the text. A few photographs are welcome, but the Committee suggests the chapter authors work to replace purely visual graphics where possible with graphics focused on synthesizing concepts and information. Chapter 23 (US Caribbean), for example, is similarly focused on island communities and contains a variety of useful infographics and flow charts that help the reader efficiently digest the chapter's content (e.g., Figures 23.4, 23.6, 23.9, 23.12, 23.13). Chapter 29 (Alaska) has many good examples as well. Similar graphics would improve the Hawai'i and US-Affiliated Pacific Islands chapter significantly. Perhaps the photographs used currently could be integrated into new conceptual and information-focused graphics.

Relatedly, it is mentioned in the text that it is difficult to document the wide variety of island-specific changes and impacts, but it is also difficult for the reader to keep track of where and when issues are currently or expected to become problematic across the region. A table or region-wide figure showing the dominant climate-related concerns or events for specific islands in Hawai'i and US-Affiliated Pacific Islands (now and in the future) would be highly valuable in obtaining broad understanding of the issues facing the region. Figures 29.1 and 29.11 in Chapter 29 (Alaska) and Figure 8.2 in Chapter 8 (Ecosystems, Ecosystem Services, and Biodiversity) are good examples of providing broad geographical context for climate-driven impacts.

As mentioned above, the ITF SLR scenarios depicted in Figure 30.3 are not properly linked to IPCC emissions-scenarios in the caption. In general, the individual SLR scenarios from the ITF report cannot be attributed to individual emissions scenarios, as the methodology for producing the SLR scenarios mixes model runs across emissions scenarios. See the ITF report for more details. More specifically, the ITF Intermediate High scenario depicted on the right side of Figure 30.3 is not representative of the SSP3-7.0 emissions scenario as suggested in the Figure 30.3 caption. If one looks at Figure 9.28 in the IPCC AR6 report directly, there is a panel that shows a map of the median SLR expected for SSP3-7.0. The values in the Pacific region are mostly in the 70-80 cm range, roughly half of what is shown in Figure 30.3 for the same emissions scenario. The discrepancy is also apparent from the text on page 21 of the ITF report stating that the Intermediate High scenario is near the upper bound of the *likely* range (i.e., modestly below the 83rd percentile per the report) of the very high emissions (SSP5-8.5), low-confidence projection. In other words, SLR associated with the Intermediate High ITF scenario is much higher than one would expect for the *likely* range from SSP3-7.0, which does not include low-confidence projections. The authors should be careful in how they navigate the NCA5 descriptive terms for emissions scenarios (Front Matter, Table 3) and the names for the ITF SLR scenarios to be sure that what is shown is properly labeled and attributed. It is also unclear in what way this figure is adapted from Sweet et al. (2022) as stated in the caption, because there is no analogous figure in that report. If the figure is showing the gridded fields from the Sweet et al. report and this is what is meant by "adapted from," then this should be stated more directly.

There are a few additional minor issues with Figure 30.3. First, the units in the figure are in centimeters, but the text uses feet. There needs to be consistency between the units in the figure and text. Second, the figure needs markers for locations of Hawai'i and USAPI within the Pacific. Third, it is confusing that the colors stay the same, but the magnitude of the scale is different between the two rows.

There are a couple of minor issues with Figure 30.4. First, “Ocean heat content rising” is an unnecessarily technical term—perhaps just say “Ocean warming.” Second, “Habitats and species distributions changing” in the upper panel should be in the Climate Impacts panel, not the Climate Indicators panel. Habitats and species distributions are not “climate” per se but respond to climate variation.

Figure 30.10 is important but almost impossible to read in the current side-by-side format because of the small scale of the maps. The authors should consider remaking this figure with subplots stacked top to bottom while maintaining the figure width so that the small differences along the coastline can be readily seen.

In Box 30.1, the authors should be more specific about what is meant by “strong progress toward meeting” the metrics on page 30-7, lines 17-18. On the Hawai’i scorecard,¹⁷ there are 36 listed indicators (not 35 as on line 18). Only 6 of these are “on track” or “near target,” while 17 are “measuring,” and 13 are “needs improvement.” It seems that the “measuring” category has been included as strong progress, but this paints an overly optimistic picture. Gathering the relevant data and being able to track progress is certainly an achievement, but this is not strong progress toward meeting these goals. These lines should be rephrased to emphasize that much progress has been made in being able to measure progress, but there is much work to be done to get the remaining 30 of the 36 metrics into the “on track” category.

Lastly, regarding Box 30.4, the draft NCA5 report contains a dedicated Focus Feature on blue carbon that should—at minimum—be referenced within this box, and it should be evaluated to what degree this box is necessary or repetitive given that existing focus feature.

Comments on Equity and Justice

This chapter effectively integrates elements of equity and justice throughout, including environmental justice. There is a clear emphasis on traditional and Indigenous practice and ways of knowing, as well as a focus on how overburdened groups are disproportionately affected by climate change, particularly as it pertains to mental and physical health. The chapter could cross-reference Chapter 23 (US Caribbean) and Chapter 16 (Tribes and Indigenous Peoples) in this regard. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

In general, the literature review was impressively comprehensive and up to date.

CHAPTER 31: ADAPTATION

Summary

While the Committee appreciates the effort that went into this chapter, the Committee finds this chapter could more clearly address the requirements of Section 106 of the GCRA. Many decision makers do not adequately recognize the need for adaptation. Residents of the United States may not fully appreciate how they have already been affected by climate change

¹⁷ See <https://alohachallenge.Hawaii.gov>.

even after the United States has had more than 100 billion-dollar disasters in less than a decade. This chapter is an opportunity to lay out the current state of adaptation research and the need for additional research to fill critical gaps. As written, Key Message 31.4 on “climate services” reads as a prescription for services that only well-resourced communities can afford. The Committee does not intend to minimize the effort on this chapter to date but encourages the authors to reevaluate the focus of this chapter to ensure that it is written for broad audiences, communicates the opportunity and urgency of adaptation, and clearly identifies successes and gaps.

The Committee suggests reordering the key messages, described below, for a more compelling chapter. The key messages are generally well stated, are supported by each key message section, and each key finding generally ties back to the key messages concisely. The findings are consistent and supported by timely and transparent research. Many sources are used and referenced, and the chapter is written at an appropriate technical level. The Committee provides specific suggestions to make sections more digestible and of interest to broad audiences.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction for this chapter could begin by introducing and defining adaptation and why it is needed, rather than starting with mitigation. Additionally, NCA5 authors should clearly differentiate between “adaptation” and “equitable adaptation.” The third paragraph clearly introduces all the key messages in the following sections, which is appreciated.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The Committee suggests carefully considering the ordering of key messages in this chapter to help reach the broadest possible audiences. For example, authors may reorder key messages by priority to create a more compelling narrative: Key Messages 31.2 (Adaptation and Equity), Key Message 31.3 (Adaptation Governance), Key Message 31.1 (Transformative Adaptation), and Key Message 31.5 (Economics of Adaptation and Adaptation Finance). Another sequencing possibility may be to fold Box 31.1 into the initial key message. For example, Key Message 31.1 might begin with a statement along the lines of “Assessment, planning, and implementation of adaptation has progressed since the Fourth National Climate Assessment, yet most adaptation actions have been small in scale and incremental in approach (*medium to high confidence*).” Alternatively, a new Key Message 31.1 about the current state of adaptation could synthesize some of the examples of adaptation discussed in the regional chapters. Additionally, the Committee suggests authors consider removing Key Message 31.4 (Science and Services in Support of Adaptation) or revising it, as suggested below. As written, the Committee is not convinced that climate services should be elevated to the importance of its own key message compared to other important adaptation topics that do not receive similar treatment. Removing this key message would allow space for a new key message such as one focused on measuring adaptation success, which is currently addressed within Key Messages 31.1 and 31.5.

The key messages are generally well stated, though likelihood statements are not included in any of the key messages. The key message titles are topics rather than messages or statements, and should be restated (e.g., “Adaptation and Equity” could be “Adaptation Actions Can Exacerbate Social Inequities Unless Applied Through an Equity Lens.”). In general, the text supporting key messages is communicated effectively, with minor comments included in Appendix A.

Comments on Key Message Language and Supporting Text

Key Message 31.1. Transformative Adaptation

Climate adaptation actions undertaken in the United States to date have generally been small in scale and incremental in approach, involving minor changes to business as usual (*medium to high confidence*). Transformative adaptation, which involves more fundamental shifts in systems, values, and practices, will be necessary in many cases to adequately address the risks of current and future climate change (*high confidence*). New monitoring and evaluation methods will also be needed to assess the effectiveness and sufficiency of adaptation and to address equity (*high confidence*).

This section appropriately identifies challenges, opportunities, and success stories with a range of broad to very specific examples. The key message claims are assigned high confidence, but lack specific likelihood language, which may be appropriate here since there is quantitative evidence available to support these statements. This is not a strong key finding to open this chapter with. The Committee suggests changing the language and/or clarifying the confidence level.

Key Message 31.2. Adaptation and Equity

People and communities are affected by climate change in different ways (*high confidence*). The way they adapt depends on social factors, including individual and community preferences, capacity, and access to resources (*high confidence*). Unless adaptation actions explicitly address the uneven distribution of climate harms, and the historical processes and injustices involved, adaptation can exacerbate social inequities and increase exposure to harm (*high confidence*).

The Committee appreciates placing the key message section on equity early in the chapter. This section appropriately identifies the challenges, opportunities, and success stories with a range of broad examples, but lacks specific examples. The key message claims are assigned high confidence but lack specific likelihood language. Additionally, the third sentence in this key message borders on being policy prescriptive but could easily be rephrased to be policy informative. For example, the sentence could state: “Adaptations that do not address inequities can increase such inequities.”

Key Message 31.3. Adaptation Governance

Adaptation involves actors from government, private sector, and civil society organizations, who often have different priorities and approaches (*high confidence*). Adaptation decision-makers must balance competing goals while also addressing uncertainties regarding future climate change and the ways that political, social, and

technological systems will be transformed (*high confidence*). To minimize the potential for adaptation actions to benefit some at the expense of others, adaptation processes must emphasize collaboration, centralize equity and justice, and incorporate a wide range of values and knowledge sources (*medium to high confidence*).

This section appropriately identifies the challenges, opportunities, and success stories with a range of broad examples, and has a few specific examples. The key message claims lack likelihood language. The medium to high confidence level is related to minimizing the potential for adaptation actions to benefit some at the expense of others related to equity and justice. The Committee suggests clarifying this claim.

Key Message 31.4. Science and Services in Support of Adaptation

Adapting to a changing climate requires both decision-relevant climate information and evidence-based decision-making approaches (collectively referred to as “climate services”) in the face of rapid societal change and historical injustice (*high confidence*). Climate services can support equity in adaptation by intentionally addressing contextual factors, such as values, culture, risk perception, and historic injustices (*medium confidence*). Significant climate service gaps remain due to accessibility, discontinuities in sectoral and geographic coverage, and a scarcity of organizational capacity to support collaboration between communities, decision-makers, and scientists (*medium confidence*).

This section is focused on decision-relevant climate information and evidence-based decision-making approaches, which are collectively referred to as “climate services.” The Committee suggests expanding the examples in New York City, California, New Mexico, and South Dakota to include more of the “how” in order to provide references for other communities. In exchange, some of the language for how these tools could be applied theoretically could be streamlined.

Key Message 31.5. Economics of Adaptation and Adaptation Finance

Improvements have been made in estimating the costs and benefits of adaptation, although many factors influence the decision to invest (*medium confidence*). Identifying, quantifying, and tracking adaptation investments made to date in the United States is challenging (*high confidence*). Future adaptation investment needs will be significant, although projected amounts vary due to uncertainty in future emissions trajectories, associated impacts, and the timing of implementation (*high confidence*). Barriers to adaptation investment and financing remain and need to be overcome through collaboration (*high confidence*).

This section appropriately identifies the challenges, opportunities, and success stories with a range of broad to very specific examples. The key message lacks specific likelihood language. However, the Committee questions why this key message is framed using a benefit-cost framework rather than a risk management framework.

The medium confidence ranking is related to improvements in estimating the costs and benefits of adaptation. It may be more helpful to modify the statement so that the authors have a higher confidence level. This section has an opportunity to discuss co-benefits and stacking of

funds based on the “color of money” to improve “status quo” projects with funding to achieve multiple adaptation benefits.

Comments on Traceable Accounts

The traceable accounts section is clearly written but could expand on the description of confidence and likelihood intervals and bolster the discussion on research gaps. The numbering of the key messages is also incorrect in the traceable accounts section and, thus, one is missing. In general, the traceable accounts are uneven—some key messages have very short traceable accounts while others are very thorough. Additionally, the use of citations is inconsistent, and in some cases new citations are introduced in the traceable accounts that do not appear in the text supporting the key messages. The Committee suggests referring to Chapter 2 of this report for more guidance on traceable accounts.

Comments on Graphics and Boxes

Some of the images and graphics for this section are missing, which makes them difficult to evaluate. The captions are clear and robust and the figures and maps available are clear.

Figure 31.1 is an important figure, but it should define what constitutes an adaptation activity.

Figure 31.2 is missing information and visual interest could be added.

Figure 31.3 is not particularly informative and could be modified to be more specific or removed.

Figure 31.4 lacks clarity, but that may be the point that is trying to be made with the graphic.

In Table 31.1, the Committee appreciates the permanent migration or planned retreat language. The Committee suggests this language be adopted across the draft NCA5 report in place of managed retreat.

Comments on Equity and Justice

Equity and justice principles are adequately incorporated into this chapter. The Committee appreciates the key message on equity being early in the chapter and that equity and justice principles are discussed in other sections as well. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters when possible.

Comments on Literature Cited

This chapter reflects the peer-reviewed scientific literature and other sources of information cited and incorporates ample recent literature appropriate for the draft NCA5 report. However, there is a reference to foundational work related to climate services on page 31-44, line 2 that references material from 2003. More recent literature should be cited instead. This reference causes the narrative about climate services throughout this section to appear dated.

CHAPTER 32: MITIGATION

Summary

Overall, this chapter is very broad and inclusive in its coverage of mitigation and the Committee commends the chapter authors for covering mitigation so comprehensively. The chapter is very close to satisfying the requirements of Section 106 of the GCRA, and, with additions and revisions specified here, the Committee believes it will meet those requirements. The key messages are clear; however, they are sometimes overly simplified and need additional detail provided in the supporting text and traceable accounts sections. While the chapter is mostly written at a technical level appropriate for the audiences, in some places, the language includes jargon. Specific places where the language is too technical are called out in Appendix A. This chapter would benefit from adding context and in-text definitions to ensure comprehension by broad audiences with varied exposure to climate change science. For example, the introduction could do a better job describing mitigation and how it differs from adaptation, and the chapter tends to omit timescale discussions that provide context for the timeline to decarbonize, and what a decarbonized world might look like past 2030 or 2050. Some omissions are noted in the text below, but chapter authors should be able to address these concerns with limited additions to the text. Additionally, the traceable accounts need more work to describe which references support the confidence ratings and how the authors determined confidence and likelihood to be fully consistent, transparent, and credible.

Review Comments Related to the Statement of Task

Comments on Chapter Introduction

The introduction to Chapter 32 (Mitigation) is very short and could provide more context for readers new to the topic of climate change and mitigation. The Committee suggests opening the introduction with the definition of mitigation (presently paragraph two of the introduction) and then discussing the goal to stabilize the Earth's climate (i.e., shift the order of the first two paragraphs). Additionally, while the introduction does have a definition of mitigation, the Committee suggests adding some more context—for example, adding a description about how mitigation differs from adaptation, and what time frames matter for mitigation efforts and why.

Comments on Key Messages, Supporting Information, and Traceable Accounts

The key messages in this chapter reflect the current understanding of observed and projected impacts to the United States. The key messages are written in a consistent and appropriate manner that build on one another, and they reflect supporting evidence. Additionally, the titles are statements, rather than headers, which is a great way to highlight the content of the chapter and introduce each key message. The key messages appropriately include assessments of confidence likelihood and, for the most part, communicate effectively. Specific suggestions for the key message text are included below.

Comments on Specific Key Message Language

Key Message 32.1. Successful Mitigation Means Reaching Net-Zero Emissions

Greenhouse gas emissions in the United States decreased by 12% between 2007 and 2019, mostly due to decreases in coal-fired electricity generation and carbon uptake on lands abandoned by agriculture (*high confidence*). Yet US net greenhouse gas emissions remain substantial and would have to decline by more than 6% per year on average, reaching net-zero around midcentury, to meet current national and international mitigation goals (*high confidence*).

Suggested title: “Successful Mitigation Means Reaching Net-Zero Emissions by Midcentury or Sooner to Meet Current National and International Mitigation Goals.”

The Committee suggests adding a time scale to the title to be more specific and to answer the question: how soon must we reach net-zero emissions?

Regarding the key message text, the Committee suggests the following modifications:

“Net greenhouse gas emissions in the United States decreased by 13 percent between 2005 and 2019, mostly due to decreases in the energy sector related to coal-fired electricity generation (*add confidence rating here*). The United States maintains a large carbon sink that offsets 12 percent of gross emissions, primarily in forests and settlements, with less in agriculture including soil management and land-use change (*high confidence*). Presuming the US carbon sink remains relatively constant, net US greenhouse gas emissions would need to decline by more than 6 percent per year on average, reaching net-zero around midcentury and stabilizing to meet current national and international mitigation goals (*high confidence*).”

The Committee has four key concerns related to this key message and its supporting text: the data used, the benchmark years used, the discussion about offsets to emissions from abandonment of agricultural land, and the inclusion of timescales and nuance.

Data: In the supporting text and the supporting images in this chapter, the Committee suggests the adoption of a report-wide standard dataset. There is variation across chapters regarding the data sources for inventory data, which may contribute to confusion across the draft NCA5 report. The Committee suggests the NCA5 authors use EPA (2022) for discussions of net US emissions.

Benchmark Years: Additionally, the Committee is concerned about the comparison benchmark of 2007, since it does not appear in EPA (2022) (which uses 2005 as a benchmark). The authors also use 2019 reporting (EPA, 2021) rather than the most recent reporting for 2020 (EPA, 2022). This may be due to concerns about pandemic-related anomalies in the data. For instance, 2020 alone was approximately 9 percent lower net emissions as compared to 2019. Thus, using 2020 data would suggest an approximate 21 percent decline in net emissions since 2005. In summary, the Committee suggests the authors either use the latest data from EPA (2022) or explain why 2019 and 2007 are used rather than 2020 and 2005.

Offsets to Emissions from Abandonment of Agriculture Land: The Committee is concerned about the reference to offsets to emissions from abandonment of agricultural land. Primarily, there is not strong support for this in the reports cited or in the literature. The EPA report and a USDA report by Walters et al. (2021) note the increased urban tree cover that

follows forest land as the major US sinks that offset emissions in this transition. Agriculture soil management and perhaps cropland abandonment contribute less. Land-based carbon sinks are unlikely to continue increasing for a long period of time at current rates and may even decline over time as forest growth on previously abandoned cropland reaches an equilibrium. Thus, an adjustment in the expectation of land-based sinks into the future may be necessary and any “new” mitigation opportunity will necessitate a change in land management or land-use.

Equally important is the fact that EPA (2022), which is based on IPCC methodology, does not have a category dedicated to cropland abandonment. The IPCC approach accounts for GHG sources and sinks by categorizing them by the land-use category *to which the land is transitioning* (not the land-use category previously employed). For instance, sources and sinks that fall within the land-use change category (i.e., land-use, land-use change, and forestry) describe these sinks as “Forests Remaining Forests,” “Cropland Remaining Cropland,” and “Land Converted to Forest,” among others. Thus, to describe the offsets due to land that was abandoned is not consistent with the way EPA (2022) categorizes offset categories. Furthermore, the category of sinks and their numbers for 2019 are: Forest Remaining Forest = 676, Cropland Remaining Cropland = 15, and Land Converted to Forest = 100. Thus, the offsets due to abandoned agricultural land are overstated in this key message, and the supporting text.

Timescales and Nuances: The effectiveness of achieving net-zero emissions will be related to timing and duration, which the authors should mention and consider in more detail. This is perhaps one of the more significant aspects of mitigation efforts and will be related to the size of the sink necessary to offset emissions, the magnitude of overshoot, and the duration of sink activities. The Committee suggests mentioning this discussion here and discussing it in more detail under Key Message 32.3.

The Committee also suggests adding known nuances to the key message to reflect the literature base and remain consistent with other chapters in the report discussing carbon emissions and sinks. For example, the overall declines in the US forest-based carbon sink are not well-represented in this message nor is the premise that there is increased carbon uptake on lands due to abandonment of agriculture (as compared to Chapter 7 [Forests]). The Committee suggests the chapter authors work with other chapters to ensure consistency and cross-reference relevant chapters where appropriate.

Key Message 32.2. We Know How to Drastically Reduce Emissions

A US energy system with net-zero emissions would rely on widespread electrification of transportation, electrification of heating in buildings and industry, decarbonized electricity systems, and substantial electricity generation from solar and wind (*high confidence*). Low-carbon fuels would still be needed for some transport and industry applications (*high confidence*). Land-related emissions in the US could be reduced by increasing the efficiency of food systems and improving agricultural practices and by protecting or restoring natural lands (*high confidence*). Across all sectors, many of these options are economically feasible now (*high confidence*).

This key message title and message are satisfactory. The Committee appreciates the comprehensive nature of this message and the fact that it is positive.

Key Message 32.3. Additional Options Need to Be Explored

Although many mitigation options are currently available and cost-effective, the optimal mix of energy sources and technologies in net-zero emissions energy systems depends on still-uncertain technological progress, public acceptance, and future developments in institutions, markets, and policies (*high confidence*). The ideal approaches to carbon management—including both carbon capture and storage and carbon dioxide removal—are similarly uncertain (*high confidence*), as is the potential to reduce land-related methane and nitrous oxide emissions through technical interventions (*medium confidence*).

The title of this key message clearly reflects the content of the message and supporting text, though the title could be expanded to provide more clarity. The Committee suggests at least adding “to achieve net zero emissions” at the end of the title. The message discusses existing uncertainty, and the need for further research to understand the optimal mix of energy sources and the ideal approaches to carbon management. The Committee also suggests the following restated title: “Additional Research Is Needed to Better Understand the Optimal Mix of Energy Sources and Technologies to Reach Net-Zero Emissions for a Decarbonized Future.”

The confidence rankings—high and medium confidence, assigned to the uncertainty regarding the ideal approaches to carbon management and the potential to reduce land-related methane and nitrous oxide emissions—are unclear. Is it that there is high confidence about uncertainty? The use of passive voice is unclear. The Committee suggests two separate sentences here to accurately convey what the confidence statement applies to and the following language modifications:

Although many mitigation options are currently available and cost-effective, the optimal mix of energy sources and technologies in net-zero emissions energy systems depends on still-uncertain technological progress, public acceptance, and future developments in institutions, markets, and policies (*high confidence*). There is considerable uncertainty surrounding the appropriate tools for, and level of, emissions management needed (*high confidence*), including methods to reduce land-related methane (*add confidence rating here*), tools to capture and store carbon dioxide (*add confidence rating here*), and methods to reduce nitrous oxide emissions using technical interventions (*add confidence rating here*).

Similar to Key Message 32.2, this message is an accurate representation of the state of knowledge. The Committee appreciates the clear description of uncertainties that remain surrounding the future successful mix of energy sources.

Key Message 32.4. Mitigation Can Be Sustainable, Healthy, and Fair

Large reductions in US greenhouse gas emissions could have substantial benefits for human health and well-being (*high confidence*). Mitigation is expected to affect pollution, the use of land and water resources, the labor force, and the affordability, reliability, and security of energy and food (*high confidence*). An equitable and sustainable transition to net-zero emissions energy and food systems in the United States would redress legacies of inequity, racism, and injustice while maximizing overall benefits to our economy and environment (*high confidence*).

The Committee appreciates that this key message integrates equity and justice components as well as its call-out to the many sectors affected by mitigation.

Key Message 32.5. Governments, Organizations, and Individuals Can Act to Reduce Emissions

Mitigation efforts can be supported by a range of actors and actions, from choices made by individuals to decisions made by businesses and local, tribal, state, and national governments (*high confidence*). Actions with significant near-term potential include sector-based policies accelerating deployment of low-carbon technologies, city-level efforts to promote public transportation and improve building efficiency, and individual behavioral changes to reduce energy demand and meat consumption (*high confidence*). This key message has an adequate title, and its message content is satisfactory.

Comments on Text Supporting the Key Messages

Key Message 32.1. Successful Mitigation Means Reaching Net-Zero Emissions. This key message focuses on observed rather than projected trends in emissions. The Committee appreciates the context that the focus on observed trends provides toward the discussion of mitigation; however, there is broad literature modeling energy systems into the future that should also be represented here. The chapter does cover the overall changes that must occur to meet emissions reductions goals, which is great; however, the reader is left wondering what the United States might look like under various mitigation pathways at different benchmark years into the future—for instance 2030 versus 2050 or 2120. Also, the supporting text (page 3, lines 19-24) omits literature that notes that the lowest cost emissions scenarios involve the United States reaching net zero before 2050 (Schaeffer et al., 2020).

This key message and supporting text frame the changes to the “US sink” as due to agriculture abandonment, but it is actually due to “agriculture, forestry, and other land-uses (AFOLU)” more generally, with most of the changes occurring in forests. As written, the supporting text for this key message does not support the discussion about carbon uptake on lands abandoned by agriculture. More supporting text and references are needed on this topic. The Committee encourages the authors to bolster the review of the mitigation measures related to agriculture by noting that systematic changes that target mitigation can also provide adaptation benefits, such as diversification of cropping systems. Furthermore, the message, supporting text, and Figure 32.7 do not align with Chapter 7 (Forests). The Committee suggests collaboration across the two chapters to ensure the chapters are consistent regarding assertions made about net sinks and carbon uptake. If the chapters opt to rely on different literature or data, the chapter authors should explain the differences, the implications in the text, or at very least the traceable accounts.

Also omitted is a discussion of an important nuance regarding the US sink. AFOLU has potential to generate carbon sinks in the present day and into the future. The immediacy of this benefit is not overtly stated in this chapter, and it should be. The implications of this nuance are significant—existing net sinks (largely forestry based) can contribute to a false sense of security. US emissions are less than they otherwise would be due to our large net sink (forests). However, the forestry-based sink is shrinking and is at risk due in part to climate change and in part to other human activities. This is a drawback that should be explicitly stated in the chapter.

Another nuance that the Committee suggests adding to the supporting text for this key message is the important role of timing and accounting (i.e., what happens with mitigation efforts if and after we meet the net-zero goals around mid-century). It is important to emphasize when talking about mitigation, that it is not sufficient to simply reduce emissions; emissions must be *contained*, or held below a maximum level, *into the future*. Holding emissions at a certain level into the future is difficult when the “maximum level” is the total emissions that the climate system can absorb, which is an imprecise estimate, at best, and heavily vulnerable to human activity across the world.

If the chapter authors are concerned about word and page count constraints, these nuances are worthwhile to mention in the supporting text but can be discussed in greater detail in the traceable accounts section.

Key Message 32.2. We Know How to Drastically Reduce Emissions. This key message is inclusive and effective in addressing uncertainty, while also stating what is known about generation profiles and land management techniques necessary for a net-zero emissions future. Adding discussion, supporting literature, and figures that forecast the potential different energy generation profiles, land-use practices, and carbon management techniques into the future (past 2030 and past 2050) may provide context that meets the charge of Section 106 of the GCRA to project up to 100 years into the future (e.g., Schaeffer et al., 2020; Van Soest et al., 2021).

Key Message 32.3. Additional Options Need to Be Explored. This key message is inclusive; its focus is on both technical developments and deployments as well as land interventions and modifications.

Key Message 32.4. Mitigation Can Be Sustainable, Healthy, and Fair. This key message should have a more complete discussion of water use needs for many newly considered energy technologies discussed earlier in the chapter under Key Message 32.3. This discussion does not require much more space, but the text as written does not acknowledge that there are sometimes drastic increases in water use with low and zero carbon technologies (e.g., CCUS, nuclear, and hydrogen all require drastic increases in water use for operations). Citations to support a more comprehensive discussion here include Dindi et al. (2022). The supporting text for this key message also only briefly mentions critical minerals and supply chain limitations. It says merely that the supply chain is vulnerable to disruptions (page 32, lines 12-13), which is an understatement. The Committee suggests broadening this discussion to highlight the recent executive orders issued by both President Trump and President Biden, such as Proclamation No. 13817 (*Federal Register*, 2017), Proclamation No. 13953 (*Federal Register*, 2020), Proclamation No. 14017 (*Federal Register*, 2021a) and the Consolidated Appropriations Act (2021), and the inherent link between critical minerals, supply chain constraints, and our ability as a nation to build the technology and infrastructure necessary to mitigate emissions. Additionally, a brief discussion on supply chains should reference the Focus on Risks to Supply Chains, which may limit additional text needed.

Key Message 32.5. Governments, Organizations, and Individuals Can Act to Reduce Emissions. The Committee suggests the chapter authors define the Paris Agreement early in the chapter, preferably the first time it is mentioned. The chapter should help educate audiences and the discussion about the Paris Agreement could be surprising. The Committee also suggests discussion of the Inflation Reduction Act (IRA) in the supporting text for this key message, particularly at page 32-36, lines 3-4. The IRA created an entirely new tax credit scheme that not

only increases available tax credits but also leverages protections for workers and populations of concern. This discussion might fit nicely right before Box 32.3.

Comments on Traceable Accounts

The traceable accounts for this chapter are short, do not have citations, and do not describe the analytic process used to develop the confidence and likelihood ratings included in each key message. It is worth the considerable effort required to produce meaningful traceable accounts, especially for a chapter on mitigation, which will be read carefully by most readers of NCA5.

Because the Chapter 32 (Mitigation) traceable accounts section is lacking citations and explanation, the chapter does not identify and provide sufficient context for embedded content and does not yet reflect current scientific understanding. The traceable accounts should be revised to demonstrate *which* references support *each* confidence and likelihood statement under each key message, consistent with the more detailed recommendation provided in Chapter 2 of this report.

In addition to the broad guidance in Chapter 2 of this report, the Committee provides specific examples and questions below to help chapter authors revise this section to ultimately ensure it provides sufficient context for embedded content and reflects current scientific understanding.

In the traceable account for Key Message 32.1, chapter authors should clarify where audiences can find some of the literature discussed (e.g., “a database of 95 of the most recent and detailed energy system scenarios of net-zero US emissions produced by X independent models”—this should be clearly cited so that audiences can find that information). Additionally, the sentence, “a large body of literature also supports the opportunities...” needs clarification and references.

In the traceable account for Key Message 32.3, there should be a discussion about how the lack of literature informs the confidence rankings. Additionally, the explanation for how the authors reached their confidence ranking is not clear, nor is it clear what the medium confidence is assigned to. Is it that the authors have medium confidence that the options to reduce land-based emissions can be reduced using available practices or is it that there is medium confidence that the best methods to do so are not yet known? The Committee suggests that the chapter authors resolve this lack of clarity both in the key message itself and in the traceable accounts section.

Comments on Graphics and Boxes

The graphics require some attention to improve their ability to convey information to broad audience bases. A few comments are offered below to improve the utility and clarity of graphics and their captions. The figures should be self-contained, which means they should have instructive captions that help audiences understand the content of the figures and how to read them. For some readers, the graphics will be their point of entry to the chapter as they decide whether they want to read the chapter (or parts thereof). Specific suggestions to improve the utility of the figures and captions are provided below.

In Figure 32.1, “US territories” should be defined in the caption.

Figure 32.2 should include a statement clarifying what (1900 = 100) means and adding labels to the x and y axes.

In Figure 32.4, it is hard to see the motorcycle line in image (a) and it is, likewise, hard to see LPG, electricity, and aviation gasoline in image (b). The Committee suggests a different order or colors for the lines.

The Committee suggests using a different color in Figure 32.5 for the fossil fuel combustion line in image (a) because it is currently hard to see.

Chapter authors should consider integrating the supporting text with Figure 32.7 and caption text discussing land-use emissions to improve the clarity of the supporting text. The caption is much clearer than the supporting text. Additionally, Figure 32.7(b) is confusing. The two blue lines are so close they are hard to distinguish. The Committee suggests using a different color for one of them. The caption should also call out lines for land-use emissions and emissions intensity of land-use in the explanatory caption.

In Figure 32.9(a), the Committee suggests gas and hydrogen use different colors because it is difficult to differentiate between the two blue shades. Additionally, it might be helpful to add a sentence comparing the Figure 32.9(a) and (b) depictions of GW generated per year to draw attention to the stark increase needed.

The caption for Figure 32.12 should include more text—it is hard to tell without the image here to evaluate, but there does not appear to be enough descriptive text in the caption.

The caption of Figure 32.15 says “Not surprisingly, ...” which seems a bit opinionated or borderline prescriptive. Chapter authors should consider omitting the “Not surprisingly” to be more neutral.

The caption of Figure 32.18 could use additional detail to facilitate understanding by general audiences, including: how the maps were drawn; defining what red, green, blue, and yellow indicate on the map, and explaining a box plot.

Figure 32.19 should define what commodities are represented in the figure by each category of NIR percent.

Figure 32.20 should explain how “mitigation activities” are defined. Many states have taken actions to reduce emissions or reach net zero even if they have not passed legislation mandating a clean energy standard, renewable energy standard, emissions reduction goal, or the governor has not issued an executive order requiring mitigation. Some cities and universities have acted in absence of their state leading the charge. The Committee suggests clarifying what was included and what was omitted.

In Figure 32.22, it is unclear if the abatement estimates are correct, and specifically if the image considers the new IRA tax credits when calculating the costs; the caption should detail this information. The structure of the figure is adapted from Figure SPM.7 in IPCC (2022b), but the cost option for which implementation is cheaper than the conventional alternative shown in Figure SPM.7 are not shown in Figure 32.22. The figure caption should describe why this data was not included.

Comments on Equity and Justice

The Committee suggests adding some framing of equity- and justice-related issues in the introduction. equity and justice principles are well incorporated into a focused section of the chapter; however, the Committee suggests more integration throughout the chapter where

possible. The chapter, as well as the cohesiveness of the report, will benefit from cross-referencing related equity and justice issues from other chapters as appropriate.

Comments on Data and Analyses

Some of the images and discussion points about carbon sinks and agriculture and forests do not align with Chapter 7 (Forests), detailed above. This discussion should be consistent across chapters, or the discrepancy should be noted, particularly in each chapter's traceable accounts sections.

Comments on Literature Cited

The chapter accurately reflects the peer-reviewed scientific literature, with a particular focus on literature since NCA4. Suggestions for additions to literature cited are provided above.

Other Recommended Changes

Geoengineering is not specifically called out by name, nor is it largely discussed (the Committee only sees discussion of geoengineering topics on page 32-22, lines 33-37, and this discussion focuses on ocean-based carbon dioxide removal methods). There is emerging literature on this topic (e.g., NASEM, 2021), which might be worth mentioning and discussing in the traceable accounts section in more detail.

The chapter could emphasize AFOLU methods to reach net zero more. Along these lines, mitigation using AFOLU methods is discussed conceptually as “interventions” rather than “management techniques.” The Committee suggests the chapter authors review and edit the text of this chapter for precise terminology when referring to land-use change and land-use management. The term “land-use change” usually refers to converting lands (typically, from forest lands to agricultural lands), while the term “land-use management” usually refers to fertilizer applications, range management, and other practices. These are two separate management techniques and should be distinguished in the chapter.

Chapter authors may consider adding a discussion about the ongoing difficulties with SEC filings (Curtis et al., 2021). The Biden administration recently published new rules requiring corporate filings on climate risk and accountability. While the scientific base provides guidance on how to conduct land-based accounting, private industry has not yet developed common practices for reporting land-based emissions reductions. Some of these details are covered in other chapters (e.g., Chapter 19 [Economics] and the Focus on Risks to Supply Chains), and this chapter should at a minimum cross-reference those other chapters, include a brief discussion, and ensure language is consistent. Discussing the same issues in multiple chapters would serve readers who only read certain chapters.

FOCUS ON COMPOUND AND COMPLEX EVENTS

Summary

This Focus on Compound and Complex Events is well written at an appropriate technical level and includes useful examples of the compound events that are its focus. However, the text does not discuss the “complex events” as suggested by its title; the Committee suggests that a discussion of cascading hazards might be a better partner for the compound events that are the main focus. The key message in the Focus does not include confidence or likelihood statements, nor does the traceable account, which should be included for consistency with other key messages and Focus On... Features, as recommended in Chapter 2 of this report. Additionally, the text could integrate equity and justice issues into earlier sections to add more real-world context and motivation for both the compound events as well as the equity and justice issues discussed the final section on “Adaptation.” Finally, the examples used are broad and the references provide a narrow perspective. The Committee suggests several citations describing hazards and events from a first responders and planners’ perspective that would provide more immediacy for readers.

Review Comments Related to the Statement of Task

Comments on the Key Message, Supporting Information, and the Traceable Account

Comments on the Key Message

Key Message: Climate change is increasing the likelihood of compound events—simultaneous or multiple back-to-back climate hazards—across every US region. Compound events impose greater harm on society and natural systems than singular events and can reduce the ability of overburdened communities to effectively respond and recover. Building climate resilience requires preparing for increasing compound event risks through new infrastructure design, planning, and disaster preparedness.

The key message is written clearly and concisely at the appropriate technical level; however, it may be useful to acknowledge the difficulty of conceptualizing or incorporating the actual range of possibilities presented by the broad class “compound events” in almost any locale.

Overall, this Focus is well integrated with the other chapters with about 20 different references to other chapters and their key messages. Other chapters should similarly cite this Focus where they currently do not (e.g., Chapter 12 [Built Environment, Urban Systems, and Cities]).

The Focus is titled “Compound and Complex Events” but (1) the key message does not mention “complex events” at all and (2) the supporting discussion only defines “complex events” at the bottom of the long list of forms that compound events can take and never returns to the subject. The Committee suggests dropping “Complex Events” from the title, or perhaps instead including “Cascading Events” in its place (see the other Recommended Changes section below).

Lastly, the key message does not include confidence or likelihood statements at all; these should be added for consistency (see Chapter 2 of this report).

Comments on Text Supporting the Key Message

A more explicit example of what “strained disaster response resources” refers to in the third bullet under “What are Compound/Complex Events” would be useful. Simultaneous megafires (even without the hurricanes) strain response resources but also regularly disrupt provision of living needs—for example, food, water, power, motor fuel, and communications supply lines—far and wide; referencing only “strained response resources” makes the problems seem more localized than they are. If a reference is needed, consider Albano et al. (2016) for an example of the ripple of disruptions a flood can engender. This is also a suitable place to better integrate Figure F1.1 into the Focus.

Under the “Climate Change” section, there is no mention of the modeling work done by Swain et al. (2018) on increasing odds of climatic “whiplashes” under climate change. This widely reported work offers an opportunity to make some of this discussion more quantitative and concrete and provide examples that readers will have encountered in the media in recent years.

As another example, it may be worth considering that in large areas of the west, wet years projected in the region cause floods, but also drive increased vegetation growth that, in many grass- and shrublands, result in significant increases in wildfire activity in the following summer(s) (e.g., Westerling et al. [2003], or subsequent studies).

Comments on the Traceable Account

The traceable account is well written, albeit too short, and with insufficient information. It fails to bring the discussion back to the specific issues of confidence and likelihood and includes only two citations to supporting literature. Thus, it does little to technically support of the body of the Focus. Additionally, there is no process description including how authors for this Focus were chosen from the NCA5 author team or what perspectives they provide. The traceable account should follow the recommended framework provided in Chapter 2 of this report.

Comments on Graphics and Boxes

There is one graphic (Figure F1.1), which illustrates west coast/east coast sequencing of disasters during fall 2020 through the end of 2021, with the COVID-19 pandemic ongoing, and the September 15, 2020, national-scale compound simultaneous wildfires and storms events. This graphic certainly shows how events can compound either at a single time or over months. The figure is well done, but has many “moving parts,” making it difficult to interpret overall, including six different “layers” (from a timeline on top to a separate one-day snapshot on the bottom, with three geographic levels and COVID-19 in between). As such, despite the many ways the figure illustrates concepts in this Focus for readers who can follow it, it may be helpful to separate it into two figures (at least)—specifically, everything above the bottom (September 15) panel versus that panel, and then decide whether both figures are necessary. The figure caption describes the intent of the figure but not what it shows or how to interpret it; the caption

should be a stand-alone explanation of the figure, targeted at the intended audiences. Finally, the figure is used as a graphic for the “Recent Examples” section, but it could be better integrated into the discussion.

Comments on Equity and Justice

Equity and justice finally appear in the “Adaptation” section, although it could also have been incorporated into the “Recent Examples” section to illustrate disproportionate impacts of compound events. Examples could include disproportionate impacts from COVID-19 or the lack of drought-response resources and monitoring on tribal lands (e.g., Hiza-Redsteer and Wessells, 2017).

The statement on page F-4, lines 7-9, about investments in improving infrastructures, community-level resources and governance are reasonable (if vague) recommendations, but verge on being policy prescriptive. It can be difficult for planners and policymakers to predict what accommodations are needed to avoid or respond to compound, complex, and cascading events given the uncertainties involved in designing useful scenarios for planning purposes. It would be appropriate to acknowledge challenges communities face in making investments and infrastructure improvements, especially communities with limited adaptation resources and capacity.

Comments on Literature Cited

This Focus provides, given length restrictions, a reasonable introduction to the state of knowledge on these topics, with some exceptions mentioned above. Some additional concrete examples of compound and, especially, cascading events and risks from the responders’ point of view would be helpful (e.g., Albano et al., 2016; Gerlak et al., 2021; Green et al., 2017; Toland et al., 2022).

Other Recommended Changes

As suggested above, “cascading risks or events” might be a more useful replacement for “complex events,” which is essentially missing from this Focus. “Cascading risks or events” are sequences of impacts and repercussions from some initial climate events that cascade down through (often unanticipated and generally difficult to anticipate) connections to ultimately be felt in ways that appear on the surface appear to be quite remote (geographically or sectorally) from the initial impact. For example, major flooding or transportation disruptions (e.g., from a snowstorm) can disrupt electrical supply that in turn disrupts delivery of gasoline and diesel at gas stations, further disrupting the ability of utilities and first responders to address the initial impacts and/or to safeguard vulnerable residents of hospitals and nursing homes (Albano et al., 2016). California wildfires in recent years have been extremely challenging, but a largely unexpected ramification has been water quality impacts in nearby communities and domestic water supplies even in areas not thoroughly burned or far downstream, resulting in economic disruptions and human health challenges long after the wildfire is quelled. Including examples of these types of cascading events would be highly relevant to this Focus.

FOCUS ON WESTERN WILDFIRES

Summary

The Focus On... Feature is generally well stated and supported by the text, with findings documented in a credible way, and written at an appropriate technical level. However, there are two major omissions. First, the Focus does not include projections of future wildfire regimes under climate change scenarios, even though there are models that exist (e.g., Littell et al., 2018; Westerling, 2018). Fire regimes are difficult to predict under novel, historically unprecedented “non-analog” conditions, owing to strong feedbacks and interactions with vegetation dynamics, ignitions, topography, and so forth. The predicted impacts of climate change on fire regimes, while dire in some western ecosystems, are very difficult to forecast, but the available projections and associated challenges should be included. Second, the Focus does not mention the effect of increased wildfire size and severity on the mitigation potential of western forests, for example, by carbon sequestration. These effects are uncertain, but should be listed as a knowledge gap, or at least, the Focus should refer to other chapters that cover this issue such as Chapter 7 (Forests). In general, though, the Focus does a good job of citing some other chapters (e.g., Chapters 14 [Air Quality], 15 [Human Health], 28 [Southwest]).

Review Comments Related to the Statement of Task

Comments on the Key Message, Supporting Information, and the Traceable Account

The Focus accurately communicates that wildfires are a critical issue related to global change, which has become more prevalent since NCA4. The Focus describes the increase in large, severe wildfires in the West that has degraded ecosystems and biodiversity, leading to flooding and reduced water quality, destroying infrastructure, and producing air pollutants including PM_{2.5} that harm people close to and far from the fire.

Comments on the Key Message

Key Message: Climate change is leading to larger and more severe wildfires, bringing acute and chronic impacts both near and far from the flames. Wildfires have significant public health, socioeconomic and ecological implications for the entire country.

The key message accurately represents the current understanding of the observed impacts of climate change as it relates to wildfires in the United States and the associated challenges.

Overall, the key message is written in a consistent and appropriate way and communicated effectively. There is no confidence/likelihood assigned to the message which should be added for consistency with other key messages (see Chapter 2 of this report). Additionally, the key message for this Focus is not specific to the western United States while the remainder of the text is. A key message more specific to the title of the Focus would insert “in the western United States” after wildfires in the first sentence.

Comments on the Text Supporting the Key Message

The text supporting the Focus explains (and represents current understanding) that vegetation management, development patterns, human caused ignitions, and warmer, drier conditions (climate change) have led to an increase in area burned and in burn severity in the western United States. To a lesser extent, the supporting text addresses projected impacts in the United States, and opportunities and success stories for addressing risk, but could enhance these areas by referencing other chapters.

To improve the clarity and communicate the message more effectively the Committee suggests using more explicit terms and a more precise chronology. Here is an example of alternative wording for page F2-4, lines 1-4:

Nineteenth and early 20th century logging and grazing, followed by a policy of fire suppression (intended to end Indigenous as well as settler burning), led to fuel buildup in low-elevation fire-adapted western forests in the late 20th century. Urban, suburban and exurban development in the last 50 years has greatly expanded the wildland-urban interface bringing people and their infrastructure adjacent to fire-prone wildlands. In the 21st century, warmer drier conditions have led to widespread bark beetle infestations and tree death, adding more fuel.

The Focus correctly points out—representing current understanding—that non-forested regions behave differently than low-elevation fire-adapted forests, although more mesic (those with adequate moisture) and high elevation (cooler, wetter) subalpine forests are not really addressed in the Focus. However, it is an overgeneralization to say that (page F2-4, lines 10-11), “In nonforested regions, changes in the frequency and extent of wildfires are being driven primarily by invasive annual grasses that have benefited from climate change.” This lumps together sagebrush steppe, desert scrub, oak savanna, and chaparral shrublands ecosystems where somewhat different global change drivers have altered (or introduced novel) fire regimes. The statement is most correct for sagebrush steppe and desert scrub, nonforested ecosystems naïve to fire. In savanna rangelands, non-native annual grasses have been established for 200 years (not primarily driven by climate change). The Committee suggests changing the sentence to “in *some* nonforested regions, *primarily the interior arid shrublands and steppe*, changes in the frequency and extent of *novel* wildfires are being driven primarily by invasive annual grasses that have benefited from climate change” (e.g., Bradley et al., 2018; Fusco et al., 2019; Nagy et al., 2021).

Fire-adapted chaparral shrubland ecosystems with wind-driven fire regimes are qualitatively different from forests (see Keeley and Syphard, 2019). This is important because southern California urban areas where 20 million people live are surrounded by these ecosystems. All of these “non-forest” ecosystems are suffering from too much or too frequent fire, with ecological consequences (Syphard et al., 2022) but this is not driven by climate change or by buildup of woody (“ladder”) fuels and therefore [woody] “fuel treatments” and “vegetation management” are likely to be ineffective and to have negative ecological effects. A sentence could be added to this effect (following page F2-4, lines 10-11), for example:

In other non-forested regions, including oak savanna and chaparral shrublands, fires are weather limited, not fuel limited, and historical increases in fire are

linked to human ignitions and land-use, not climatic factors like high temperatures and drought; those increases are degrading shrubland ecosystems. (Keeley and Syphard, 2019; Syphard et al., 2022)

This Focus, importantly, addresses the knock-on effects of larger, more severe fires on plant and animal species, representing current understanding of the observed impacts and challenges. Major smoke events associated with recent western wildfires have had regional, national, and even global impacts on air quality and human health. Fire also affects water supply and water quality, and therefore critical infrastructure. The following could be reworded, however, to be more accurate (page F2-4, lines 29-30): “Although electricity grids do not cause a large number of fires, some fires they have caused were large and deadly.” In fact, the vast majority of wildfires are small, but it is the large wildfires that are of concern, and power lines have caused many of them, at least in California. The sentence could be changed by adding at the end, “and large fires have the greatest impact on lives and property, as well as ecosystem.” The next sentence (page F2-4, lines 31-33) correctly states that “[public safety power shutoffs] negatively affect local economies and key sectors.” However, it should be emphasized even more that these negative impacts disproportionately affect the lives and livelihoods of rural and overburdened communities, not just “key sectors” in the abstract. The public safety power shutoffs are in fact very controversial—the for-profit utilities would rather turn off the power than upgrade their infrastructure—and this could also be noted. It could also be mentioned that urban emergency plans that limit escape routes from neighborhoods are upstream hazards as well. Finally, the Focus should include some mention of projected future trends in western wildfire under climate change scenarios, and their uncertainty. Projections for some regions are dire (e.g., Abatzoglou, 2021; Littell et al., 2018; Westerling, 2018) and are being used by regional and national land management agencies for planning.

Comments on the Traceable Account

The traceable accounts section effectively describes the evidence for the link between recent climate warming and wildfire, citing the literature that established a link between climate change, increased fuel flammability, and increased burned area.

Uncertainties in research and information gaps were not described but would enhance the traceable account and be more consistent with other chapters. For example, there is still uncertainty about the efficacy of fuel treatments in different forest types. The “strong evidence” (page F2-5, line 35) mentioned in this section and in the main text should be qualified to delimit that “reducing fuels and decreasing stand (tree) density may lessen the impact of climate-driven stress and disturbance” only pertains to forest, and only certain (low-elevation) forests at that and does not just refer to wildfire (the stresses that may be lessened include drought and insects outbreaks). Another information gap that could be noted is the projected effect of future climate change on western wildfires. There are projections, but they are highly uncertain, discussed above.

This traceable account section does not have citations. The section should follow recommendations in Chapter 2 of this report to remove broad statements about the literature and include citations already provided in the main text. Consistent with the suggestion to include confidence/likelihood statement(s) with the key message, the traceable account should also describe how confidence/likelihood were assigned and what evidence was used.

Comments on Graphics and Boxes

Figure F2.1 is helpful in illustrating the chain of events from wildfire drivers to impacts. It is explained that fire-exclusion and land-use practices in low-elevation fire-dependent forests have led to fuel accumulation, although “vegetation management,” “land-use practices,” and other concepts could be replaced with more explicit terms and a chronology of policy and land-use decisions should also be provided. Also, it is not immediately obvious to read the figure from the bottom up. The Committee suggests either reordering the images in the figure to read from top to bottom or providing clear directives, such as arrows and a description in the figure caption for how to read the figure. The figure caption is somewhat repetitive of the text in the figure and should instead guide the reader to understand its meaning.

Comments on Equity and Justice

The Focus addresses some of the equity and justice dimensions of increasing western wildfires, although its statement of the evidence for the broader disproportionate impacts on overburdened populations could be strengthened. The Focus correctly points out, for example, that wildfire smoke disproportionately harms poor people (note “socioeconomic status” or “vulnerable population” should be made consistent with terminology chosen for the report overall; see Chapter 2 of this report), but it could be emphasized even more strongly that all fallout from climate-driven disasters including large wildfires disproportionately harms people with low income and people who have historically been discriminated against because they have less access to health care, more comorbidities, and less resources (i.e., money, insurance).

The “farmworkers and other outdoor workers” at risk from wildfire smoke (page F2-5, line 10) are frequently low-income workers from immigrant and Indigenous communities so this human health impact is an environmental justice issue. The paragraph regarding wildfire smoke (page F2-5, lines 4-12) does reference Chapter 15 (Human Health), but Chapter 15 does not directly address the risk posed to farmworkers. Méndez et al. (2020) could be added to the citations. Page F2-4, line 35, mentions populations residing in the wildland-urban interface but does not mention who those populations are and the relevant stressors that have driven increased development there.

Comments on Data and Analyses

The Focus could briefly state the changing extent of large western wildfires in recent years. Chapter 7 (Forests) does so, for example, stating: “Area burned by high-severity wildfires (e.g., stand-replacing fires) has increased in the West by about eightfold since 1985 (Parks and Abatzoglou 2020).” Chapter 7 (Forests) could also be cited, but it seems worth reporting this basic fact in this Focus.

FOCUS ON COVID-19 AND CLIMATE CHANGE

Summary

Overall, this Focus Feature is well written, flows logically, and drives home the important points related to climate change and pandemics, using COVID-19 as an example. The key message provides a high-level overview before delving into the details and nuances in the supporting text, though the key message could be revised to better reflect the knowledge base. It is written at a suitable level for general audiences. The traceable accounts section requires additional citations to fully support the text and reasoning in the key message. Because Section 106 of the GCRA requires NCA5 to forecast 25 to 100 years into the future, it will be important to emphasize that there will be future pandemics, possibly during that time period.

Review Comments Related to the Statement of Task

Comments on the Key Message, Supporting Information, and the Traceable Account

Comments on the Key Message

Key Message: Climate change has exacerbated the devastating impacts of the COVID-19 pandemic. Climate-driven changes in ecosystems alter susceptibility and interactions among humans, pathogens, and animals, increasing risk of emerging infectious diseases. Climate change also amplifies the risk of infection among people at the frontlines of exposure, especially those with fewer resources. Addressing the challenges of climate change and the COVID-19 pandemic requires early, collective action and systemic change.

The first sentence in the key message makes the overarching statement that “climate change has exacerbated the devastating impacts of the COVID-19 pandemic;” however, there is only one reference in supporting text that could be directly attributed to this statement and that reference supports the statement that “over half of known human pathogens are exacerbated by climate change,” not the premise that climate has exacerbated the COVID-19 pandemic. In addition, the supporting text goes on to undermine the first statement in the key message when it states that “our understanding of COVID-19 is evolving.” The Committee is concerned by the lack of literature to support this strong of a statement, particularly regarding a topic that has been at the forefront of national and global attention. The Committee suggests the following modified key message to address its concerns:

Proposed Key Message: Climate change has potential to exacerbate pandemics. Climate-driven changes in ecosystems alter susceptibility and interactions among humans, pathogens, and animals, increasing risk of emerging infectious diseases like COVID-19 (*add confidence and likelihood ratings*). Climate change also amplifies the risk of infection among people at the frontlines of exposure, especially those with fewer resources (*add confidence and likelihood ratings*). Addressing the challenges of climate

change and pandemics requires early, collective action and systemic change (*add confidence and likelihood ratings*).

Structurally, the key message is lacking a title and would benefit from using a similar format to the rest of the key messages in the report (i.e., using a title, a message, confidence ratings, and supporting text). The Committee is also concerned that there are no corresponding confidence and likelihood ratings for the first statement in the key message to help gauge the level of scientific understanding behind the assertion. Confidence and/or likelihood statements should be added to the key message for consistency with other key messages (see Chapter 2 of this report) and the traceable accounts section should likewise discuss analysis and supporting evidence for those statements.

Otherwise, the message itself is comprehensive and inclusive, integrates equity and justice—climate change can amplify risk of pathogenic infections for those on the front lines of exposure or with fewer resources—and notes the need for investments in health and medical infrastructure, improved surveillance, and dissemination of public health information. The Committee suggests adding text that recognizes that the next pandemic could arrive much sooner than a century, and that it may be the result of malign agents, described below.

Comments on Text Supporting the Key Message

The supporting text that discusses the “impact of climate on infectious disease” is well written and clear, and it cites excellent write-ups and graphics in Key Messages 8.2 and 15.1.

The supporting text that discusses how “interactions between COVID-19 and climate change can exacerbate existing inequities” is well written. In general, specific comments would be more effective than broad ones. For example, on page F3-2, line 23, rather than reflecting that Hurricane Laura increased COVID-19 cases “significantly,” authors should report that the increase was 12 percent per week. The recent references for this section are strong. The discussion of how vulnerable communities face compounded risks from climate change that are further exacerbated by highly contagious and debilitating infectious pathogens like COVID is critical: it should be elevated beyond this Focus Feature to Chapter 1 (Overview) and Chapter 15 (Human Health).

The supporting text that discusses the “lessons learned from COVID-19 for managing climate change” is good, as is Figure F3.1. However, the figure caption is not self-contained and would be more helpful if it were to walk the reader through the infographic.

The supporting text on page F3-4, lines 1-4, would benefit from more specificity. “Acting now...” is a nod to the future but could make a stronger statement about proactive preparations for future pandemics. The Committee suggests adding a final section to the Focus Feature that would focus on the importance of nimble responses and the use of emerging technologies to respond to pandemics and climate change. The supporting text under this discussion could include suggested aspects of nimble pandemic responses including challenges of the current pandemic surveillance systems (e.g., fragmented, legally constrained, non-interoperative), opportunities for preparations before a crisis (e.g., pre-commissioned team drills to learn mutual strengths and limitations),¹⁸ and the emergence of wastewater surveillance as an early warning system (NASEM, 2023).¹⁹

¹⁸ See <https://www.washingtonpost.com/health/2022/08/17/walensky-revamp-cdc-culture-covid>.

¹⁹ See <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/wastewater-surveillance.html>.

Comments on the Traceable Account

The traceable accounts section is brief and clear; however, the authors only include one reference and do not describe the analytic process used to arrive at the key message. The traceable accounts should describe and support how the authors arrived at their key message and each statement describing a body of literature should have citations after it. The description of the gaps in understanding is great, however, and the rest of the traceable accounts section should model the discussion after that one. Consistent with the suggestion to include confidence/likelihood statement(s) with the key message, the traceable account should also describe how confidence/likelihood were assigned and what evidence was used.

Comments on Equity and Justice

This Focus makes it clear that economically disadvantaged and overburdened communities suffer greater harm when preexisting vulnerabilities—economic, racial, and economic—are compounded by pandemics.

Comments on Literature Cited

The Focus accurately reflects the knowledge base, particularly what has been learned from the COVID-19 pandemic since NCA4. The Fisher et al. (2021) citation (cited on page F3-3, line 12) should be added the reference list.

FOCUS ON RISKS TO SUPPLY CHAINS

Summary

The key message in the Focus On... Feature is clearly stated and thoroughly supported by the detail provided within the Feature. This Focus is appropriate for the intended audiences and does a commendable job of cross-referencing other chapters and Focus On... Features. There are no major concerns about this Focus, though the Committee notes a few omissions and provides suggestions for clarifications below. The only key concern is a lack of confidence/likelihood statements in the key message. Confidence and likelihood statements convey important context to key message readers about the scientific claim being made, and their inclusion would enhance the overall message and credibility of the Focus.

Review Comments Related to the Statement of Task

Comments on the Key Message, Supporting Information, and the Traceable Account

Overall, the key message and supporting text are clear, consistent, and written at the appropriate technical level for the intended audiences. The Focus prioritizes newer literature (since NCA4) and provides citations following each assertion or claim. The Committee

commends the authors for consistently cross-referencing other chapters in NCA5, thereby emphasizing the cross-cutting nature of the Focus.

Comments on the Key Message

Key Message: Damage to supply chain networks caused by climate change reverberates through people’s livelihoods and investments in ways that threaten quality of life and security, often in lasting and unequal ways. Coordinated efforts can mediate impacts and help communities and companies adapt to these large, interconnected, and recurring risks. However, the pace, scale, and scope of efforts needed to transform supply chains are not yet sufficient to meet either current or expected disruptions and costs.

The key message in this Focus reflects the current understanding of observed and projected impacts on the supply chain in the United States as well as the challenges, opportunities, and ways to address supply chain risks. The key message is written in a consistent and appropriate way and reflects supporting evidence well. The only major concern is a lack of confidence/likelihood statements of the projected outcomes and conclusions in the key message.

Comments on Text Supporting the Key Message

The text supporting the key message should include a discussion of seaports and their vulnerability to SLR (Izaguirre et al., 2021). There should also be a brief discussion about the impact of heat waves on global supply chain (Le Page, 2022). Both issues can be briefly mentioned in the second paragraph starting with “Climate-driven disruptions to supply chains...”

Additionally, the SEC has proposed new rules for reporting material risk up and down the supply chain from climate change.^{20,21} This Focus should recognize the proposed structure in the last paragraph on page F4-3 and/or cross-reference Chapter 19 (Economics) if it is included there.

Comments on the Traceable Account

The traceable accounts section does not include any process description including comments on the authorship makeup and lacks sufficient details on the methods of how authors reached the conclusions, and citations. Broad statements such as “recent lived experience confirm how supply chains are a core factor...” do not provide sufficient support for the key message and should be referenced more explicitly. The traceable accounts section should be revised with the addition of confidence and likelihood statements to demonstrate which references support the statements and how the authors made their assessment.

Comments on Graphics and Boxes

There is one figure in this Focus on the vulnerability of livestock food supply chains to drought. The figure is mostly clear and effective. However, the caption should be a standalone

²⁰ See <https://www.sec.gov/news/press-release/2022-46>.

²¹ See <https://www.fdic.gov/news/speeches/2022/spmar3022.html>.

explanation of the figure and the figure title and caption should match. There also should be an explanation about what the two different colors of arrows mean.

Comments on Equity and Justice

Equity and justice principles are adequately addressed. The Focus mentions that supply chain issues can deepen existing inequities in risk distribution and resource access for overburdened communities. The Committee notes the inconsistent use of terminology (i.e., “vulnerable,” “marginalized,” and “overburdened”) and suggests that the terminology should be consistent throughout both the Focus and the draft NCA5 report. Additionally, as noted in Chapter 2 of this report, authors should make an effort to avoid harmful terms like “marginalized” when describing impacted communities.

Comments on Literature Cited

This Focus cites papers from well-respected journals and reports from major agencies such as the Electric Power Research Institute and the California Energy Commission, most of which were published since the last NCA. However, there is a lack of citations in the traceable accounts section, discussed above.

FOCUS ON BLUE CARBON

Summary

The Focus on Blue Carbon is well written and informative but could benefit from the addition of confidence statements and a discussion of the feedback on the climate system if conservation and restoration efforts are not undertaken.

Review Comments Related to the Statement of Task

Comments on the Key Message, Supporting Information, and the Traceable Account

Comments on the Key Message

Key Message: Blue carbon refers to carbon captured by marine and coastal ecosystems, such as mangroves, coastal wetlands, and seagrasses. Coastal ecosystems sequester carbon at a much faster rate than terrestrial ecosystems, and the carbon stored belowground can remain in place for decades to millennia if undisturbed by humans or extreme events. Although carbon sequestration in coastal ecosystems is not a new phenomenon, use of the term blue carbon has increased because conservation and restoration of coastal ecosystems may play a role in mitigating global carbon dioxide emissions.

The key message is well written and mostly reflects current understanding, but it could be improved in the following ways. The Committee suggests that the authors include confidence statements for the second and third sentences in the key message, especially on the possibility that blue carbon may play a role in mitigating global CO₂ emissions. The Committee also suggests that the third sentence be shortened to focus less on usage of the term “blue carbon” itself (which can be moved to the supporting text) and more on the importance of conservation. The third sentence could simply state, “Conservation and restoration of coastal ecosystems may play a role in mitigating global carbon dioxide emissions by increasing sequestration of blue carbon” and provide a confidence statement.

Comments on Text Supporting the Key Message

In general, the supporting text is well written and targets an appropriate technical level, but the Committee suggests the following changes. First, it should be made clear for readers not familiar with the terminology that the term “marine” does not include freshwater ecosystems. Second, the chapter highlights that SLR and extreme events are the greatest threat to blue carbon ecosystems, but it would be helpful to know if other effects of climate change on marine environments (e.g., temperature, ocean acidification) have an impact. Third, much attention is paid to the potential for carbon sequestration in marine ecosystems to mitigate climate change, but there is no mention of the feedback on climate change if conservation and restoration efforts are not undertaken—for example, accelerating SLR degrades blue carbon ecosystems, reducing carbon sequestration, further accelerating warming and SLR, which further increases the rate of ecosystem degradation and so on. Finally, the content of this Focus does not specifically discuss the role of or impacts on blue carbon systems in the United States. The supporting text could be expanded to include information about specific US locations that are particularly important and/or threatened by SLR and extreme events. Along these lines, the Committee notes that this Focus is only referenced by three national-level chapters (Chapters 9 [Coastal Effects], 10 [Oceans and Marine Resources], and 32 [Mitigation]) and no regional chapters. The Committee suggests that the authors of this Focus work with authors of regional chapters to cross-reference between the relevant ecosystems discussed in the regional chapters and the importance of these ecosystems described in this feature.

Comments on the Traceable Account

Consistent with the suggestion above that confidence statements be added to the key message, the Committee suggests that the rationale for the confidence statements be added to the traceable account. The Committee also suggests adding a statement describing the process and rationale used to compose the author team for consistency with other chapters and recommendations in Chapter 2 of this report.

Comments on Equity and Justice

Equity and justice are not discussed in the Focus, but given the narrow focus, this is not a major concern.

Comments on Literature Cited

Few references are provided for statements regarding the effect of extreme events on blue carbon ecosystems. If this due to a lack of literature on the subject, this should be added as a research gap in the traceable account, and noted as an uncertainty in the main text, as appropriate. Otherwise, the literature review of this effect could be expanded.

Other Recommended Changes

The Committee notes there is a box in Chapter 30 (Hawai‘i and US-Affiliated Pacific Islands) that also discusses blue carbon. The authors of this Focus and the authors of Chapter 30 (Hawai‘i and US-Affiliated Pacific Islands) should coordinate to (1) decide whether both the box and the Focus are necessary and (2) cross-reference if both are deemed necessary.

APPENDIX 3: SCENARIOS AND DATASETS

Overall, this is a solid annex although, as discussed in the review of Chapter 3 (Earth System Processes), authors should make sure that the discussion of IPCC emission/concentration scenarios is consistent between the Front Matter, Chapter 3 (Earth System Processes) and Appendix 3 (Scenarios and Datasets) and consider whether Key Message 3.4 is necessary given the availability of this Appendix.

This Appendix is the only place in the report where the sea-level scenarios are introduced. This section should be expanded because the way that sea-level scenarios are generated is not entirely consistent with the IPCC scenarios as usually referenced, but this is not clear from the Appendix. The authors should add: (1) a discussion of overlapping names between SLR and emissions scenarios, (2) an overview of the method by which the SLR scenarios are derived from IPCC/CMIP6 projections, and (3) a discussion of how Table 2.4 in Sweet et al. (2022) and the likelihood language in the Front Matter of the draft NCA5 report can be combined to make likelihood statements for the SLR scenarios.

APPENDIX 4: INDICATORS

The topic of climate change indicators is of growing importance and the Committee commends the draft NCA5 report for including this appendix. EPA has for years published reports on indicators.²² In general, the examples of indicators in the appendix are sound, other than the presentation of billion-dollar damages (described below). However, the Committee suggests better integrating this important appendix throughout the draft NCA5 report. Appendix 4 is only referenced in three chapters: Chapters), (Overview), 15 (Human Health) and 26 (Southern Great Plains). The NCA5 authors could also consider mentioning the following indicators in the following chapters:

- Greenhouse gases in Chapter 2 (Climate Trends)

²² See <https://www.epa.gov/climate-indicators>.

- Temperature and extreme heat in national Chapters 2 (Climate Trends), 3 (Earth System Processes), 12 (Built Environment, Urban Systems, and Cities), and 14 (Air Quality) as well as all regional chapters
- Precipitation in Chapter 2 (Climate Trends)
- Extreme events in Chapters 2 (Climate Trends) and 3 (Earth System Processes) and other chapters, as appropriate
- Sea ice in Chapters 2 (Climate Trends), 10 (Oceans and Marine Resources), and 29 (Alaska)
- Snowpack and snow cover in Chapters 2 (Climate Trends), 4 (Water), 27 (Northwest), 28 (Southwest), and 29 (Alaska)
- Flooding in Chapter 4 (Water) and regional chapters, as appropriate
- Drought in Chapter 4 (Water) and regional chapters, as appropriate
- Sea-level rise and coastal flooding in Chapter 9 (Coastal Effects)
- Marine heat waves in Chapter 10 (Oceans and Marine Resources)
- Marine species in Chapters 8 (Ecosystems, Ecosystem Services, and Biodiversity) and 10 (Oceans and Marine Resources)
- Seasonal change in Chapters 6 (Land Cover and Land-Use Change), 7 (Forests), and 8 (Ecosystems, Ecosystem Services, and Biodiversity)
- Wildland fire in Chapters 6 (Land Cover and Land-Use Change), 7 (Forests), and 8 (Ecosystems, Ecosystem Services, and Biodiversity)
- Agricultural productivity in Chapter 11 (Agriculture, Food Systems, and Rural Communities)
- Adaptation and mitigation in Chapters 31 (Adaptation) and 32 (Mitigation)

The appendix presents trends in type and number of billion-dollar disasters as an example of how extreme events have changed. While there may be a signal of change in extreme events that have caused billion-dollar disasters, the larger explanation of the increase is most likely due to exposure (see Smith and Katz, 2013), such as increase in population in hazardous areas and growth in the value of property in exceedance of the Consumer Price Index used to deflate the value of disasters. The Committee's comments on the billion-dollar disaster figure in Chapter 1 (Overview) and 2 (Climate Trends) also point out that the figure should explain that increase is mainly the result of socioeconomic factors.

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Appendix A

Line-by-Line Comments

CHAPTER LINE-BY-LINE COMMENTS

CHAPTER 0: FRONT MATTER

#	Page/Line	Comment
1	P6/L2	Suggest citing United States Code since the Act is codified in non-scattered sections: (15 U.S.C. § 2921 et seq.).
2	P7/L10	Suggest adding “since the [Fourth National Climate Assessment (NCA4)]” to the text, “and how methods to understand changes in Earth systems have advanced <i>since NCA4</i> .”
3	P7-8/L15-4	Suggest consistent reference to other chapters; sometimes just the chapter is in parentheses, other times the name of the chapter and the chapter number are in parentheses.
4	P8/L1-2	Suggest including Figure 1 or specific regional maps after the introduction in each regional chapter.
5	P9/L3	Suggest “these” instead of “covered.”
6	P9/L14-18	Does “calibrated” mean calibrated with the Intergovernmental Panel on Climate Change (IPCC) terms? Suggest more precise language or defining “calibrated” or chose different phrasing: “Authors used the IPCC terms to describe confidence and likelihood in their key messages, where appropriate.”
7	P9/L19-25	Suggest a hover function where readers online can see <i>both</i> the definition of confidence and likelihood <i>and</i> the adopted IPCC scale for each term when they hover their mouse cursor over a confidence and likelihood rating (included on page 0-10, lines 1-6) in the text.
8	P13/L8-15	This paragraph is not written for broad audiences with little exposure to climate change and should be revised for clarity: suggest adding an introductory sentence to introduce global warming levels and internal variability; suggest adding a “for reference” introduction to the last sentence in this paragraph; and avoid “in which” where possible because it is unclear. “Conversely” is confusing here because it is not quite conversely—it is more of an “actually”; and the sentence in lines 11-13 uses the word “level” multiple times, which muddles the message. Suggest reworking these sentences to clarify the language as follows (from line 8 on): “Global warming levels can be impacted by internal variability in the climate system. Internal variability in the climate system means that even as the world rapidly warms, some years will be hotter, and some years will be cooler than the multidecadal average. Annual variability, for example when the global annual

average temperature is 1.5°C (2.7°F) hotter than it was from 1850 to 1900, does not mean the 1.5°C global warming level has been reached. However, annual variability like this can mean that climate impacts that were projected to occur at a given global warming level may occur even before projections indicated. In addition, temperatures in different parts of the world could be warmer than the global average. For reference, a global warming level of 2°C (3.6°F) would result in regional temperatures in parts of the United States that are more than 2°C above preindustrial levels (Figure 1.16).”

9	P13/L16-17	“Runaway impacts” is not clear; suggest revising to clarify what this phrase means.
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CHAPTER 1: OVERVIEW

#	Page/Line	Comment
1	P4/L6-7	“Worst harms” is not defined in the report. Suggest instead, “faster and deeper cuts in [greenhouse gas (GHG)] emissions are achievable.”
2	P4/L16	Should reference Chapter 3 (Earth System Processes) key message on extreme events.
3	P4/L20	Suggest citing all of Chapter 4 (Water) rather than just Key Message 4.2.
4	P4/L23	Does the evidence cited in the report demonstrate that every individual American will have less harm from reduced warming? The evidence shows some Americans having some benefits. The report does support a conclusion that a reduction in adverse impacts is correlated with less warming.
5	P4/L25	“Individuals” should be mentioned. Key Message 32.5 states that governments, organizations, and individuals can reduce emissions.
6	P4/L25-31	This paragraph should be more inclusive and discuss other low-carbon energy sources discussed at length in Chapters 5 (Energy Supply, Delivery, and Demand) and 32 (Mitigation) (e.g., hydrogen, carbon capture, utilization, and storage [CCUS], nuclear). Discussing only renewables is not an accurate picture of the state of the science, the technology, or industry.
7	P4/L28	Sustainable land-use is credited with helping to reduce emissions, but it is not clear where this is mentioned in the chapters. The chapters cited are Chapters 5 (Energy Supply, Delivery, and Demand), 12 (Built Environment, Urban Systems, and Cities), and 32 (Mitigation). The section on land-use in the mitigation chapter states that net sequestration of carbon on US land has decreased from 1990 to 2020.
8	P4/L35-36	The statement implies that the decrease was due entirely to increased use of renewables. Chapter 32 (Mitigation) notes that increased use of natural gas and renewables offsets coal use. The role of natural gas should be acknowledged.

9	P5/L4	“Risks” rather than “harms” would be more appropriate because anticipatory adaptation can be taken to reduce risk of harm. In many cases, if the harm happens, it may not be made less severe.
10	P5/L1-16	Key Message 31.4 discusses some examples of where climate services are being applied to support decision making. This should be summarized in Section 1.3.
11	P5/L11	Cite Key Message 4.2 rather than 24.4. Also note that the Committee’s comments on Chapter 24 point out such modifications are also being made to adapt to sea-level rise.
12	P6/L2-3	This is an example of a statement that is technically correct but is policy prescriptive because it implies a preference for a policy outcome. If examples of climate action that also address equity and justice can be given in the report, they can be summarized in this section of the Overview.
13	P6/L5	Suggest not using contractions in formal reports. Use “do not” rather than “don’t.”
14	P6/L7	The adverb “fairly” makes this statement policy prescriptive. The statement should be rewritten to be policy relevant without appearing to advocate a policy prescription.
15	P7/L4-6	Should add a sentence saying that studies suggest that both a more equitable and lower cost action on climate change would imply that the United States should cut emissions in advance of the global average (Key Message 32.1) (Schaeffer et al., 2020).
16	P7/L3-8	The paragraph is technically correct but leaves out a lot of important and policy relevant information. Carbon sequestration, which the literature suggests is needed to meet net zero by mid-century emissions levels, is not mentioned. In addition, the paragraph does not mention barriers to implementation of low-carbon emissions options. Also, Chapter 5 (Energy Supply, Delivery, and Demand) does not address how GHG emissions can be reduced from the energy sector but focuses on climate change impacts on that sector.
17	P7/L5	Delete “preferably” because it makes the clause policy prescriptive.
18	P7/Figure 1.1	The figure is good and informative. Is it possible to have the divergence of scenarios start around 2020? If that is not possible, the caption should explain why the scenarios diverge around 2015.
19	P7/L9	The figure depicts carbon dioxide (CO ₂) emissions, which is closely correlated, but not exactly climate futures. The Committee suggests indicating that CO ₂ is the largest driver of climate change.
20	P7/L12-14	Suggest adding a discussion of emissions and sinks in the United States and using the word “net” before “US GHG emissions.” The second sentence in this paragraph should align with any changes made in Chapter 32 (Mitigation) based on the Committee’s review (see Chapter 3).
21	P7/L13	The phrase “avoid the worst harm” is vague. The Committee suggests replacing that phrase with reference to the 1.5°C and/or 2.0°C targets in the Paris Accord.

22	P8-9/L35-1	Suggest offsetting “and are exacerbated by” with commas.
23	P9/L29-30	This sentence is unclear as written; suggest: “many communities are learning climate change response techniques from tribal and Indigenous leadership.”
24	P10/L2	Are the words “first and worst” scientifically defensible? There is literature, (e.g., EPA, 2021) that finds that, as the report terms, “minority” communities face relatively higher and hence disproportionate risks to climate hazards. But do they face these risks before other communities do? The word “worst” also seems loaded. The statement will be effective without the words “first and worst.”
25	P10/L12-13	The sentence is unclear and should be revised. Is the point that we have to adapt no matter how effective mitigation is?
26	P10/Figure 1.2	It is useful to display long term temperature trends in the United States. The figure title should show the years in the data range used to create the figure (e.g., 1900-2020). The reader may notice areas that have been cooling. The caption should address explanations for observed cooling and, if appropriate, why the western half of the country appears to be warming more than the eastern half.
27	P11/L1-2	The word “worse” in the title has a vague meaning. It would be more precise to replace it with, for example, “more frequent and severe.”
28	P11/L12	The sentence on heat and wildfire jeopardizing outdoor sports and recreation may be overstated and does not consider other benefits of higher temperatures for warm weather recreation. The verb “jeopardize” is vague and unclear as to what the effect of extreme weather on warm weather recreation is estimated to be. While there is a lot of literature on climate change impacts on cold weather recreation, particularly skiing (e.g., Wobus et al., 2017) there appears to be less literature on effects on warm weather recreation, but new literature has been published in recent years (e.g., Chan and Wichman, 2020, 2022; Gellman and Wibbenmeyer, 2022). These studies find there could be net benefits to total recreation from increased temperature but may not fully consider impacts of high heat, increased precipitation, and fire. Gellman and Wibbenmeyer (2022) addresses fire. The phrasing in the draft does adequately describe the complexity of the relationship of climate change and US recreation. This can be better addressed in the Overview and in appropriate underlying chapters such as Chapter 19 (Economics) and some of the regional chapters.
29	P12/L4-5	It is not clear why the Focus on Complex and Compound Events is cited. Key Message 4.3 and Chapter 28 (Southwest) can also be cited.
30	P12/L6-17 including Figure 1.4	The presentation of the billion-dollar disaster figure does not appropriately put the change in billion-dollar disasters in context. The paragraph in lines 6-11 attributes increase in billion-dollar disasters to “worsening weather” and line 16 states that the increase is “in part because of human caused warming.” A different figure on billion-dollar disasters is displayed in Chapter 2 (Climate Trends), but shows

the disasters that occurred in 2021, not the long-term trends. Figure 1.4 is introducing new information not in the underlying report. Line 15 states correctly that the data on billion-dollar disasters are adjusted for inflation. The National Oceanic and Atmospheric Administration (NOAA) uses the Consumer Price Index (CPI) to adjust the size of the disasters.¹ However, the exposure to such disasters appears to be increasing. Three trends should be noted to appropriately put the “Billion-Dollar Disaster” data in context. First, changes in property values versus CPI should be noted.² Second, population increased from 226 million in 1980 to 331 million in 2020—a 46 percent increase.³ Third, increased development in vulnerable areas (Iglesias et al., 2021).

31	P13/L11-12	What do the terms “significant” and “well-being” mean in this statement? The terms are vague and subject to misinterpretation.
32	P13/L30	As noted above, the phrase “first and worst” is used regarding inequitable impacts. Please use words that are supported by evidence on inequitable impacts.
33	P13/L35	Suggest defining redlining for broad audiences. The definition is included below in Section 3.3, page 1-20, lines 13-14. Suggest moving the definition up or referring readers to where it is defined.
34	P16/Table 1.2 Southwest row 2nd column	The statement about groundwater is an oversimplification. See comments on Chapter 28 (Southwest).
35	P17/L2	“The things Americans value most are at risk.” Does the report examine what Americans value most? This is a quotable statement but is it supported by the evidence base?
36	P17/L6-9	The sentence beginning “The threats to the people and places we love...” is policy prescriptive. Also, the Committee suggests removing “to unavoidable change.”
37	P17/L12-15	Not all impacts of flooding are negative. There can be some positive ecosystem benefits (see page 4-6, lines 3-10).
38	P17-18/L12-12	The section should also discuss impacts of climate change on water quality.
39	P17/L20-21	The statement about excessive rainfall is in Chapter 24 (Midwest).
40	P17/L34	The Committee agrees with the statement about vulnerability of small water systems but does not see supporting information in Chapters 4 (Water) or 28 (Southwest).
41	P17/L37	Chapter 4 (Water) does not discuss how nature-based solutions (NBSs) can improve water supplies. It does address the role of NBSs and flooding.

¹ See <https://www.ncei.noaa.gov/access/billions>.

² See <https://anytimeestimate.com/research/housing-prices-vs-inflation>.

³ See <https://www.census.gov/data/tables/time-series/dec/popchange-data-text.html>.

42	P18/L14	The Committee suggests caution in using “will” in this key statement because it implies there is virtually no uncertainty about the outcome. While the report cites published literature projecting decreases in agriculture output, uncertainties about potential changes in baseline conditions and the effectiveness of adaptation should result in some reduction in likelihood or confidence in this statement. The heading that disruptions to the food system are “expected” to increase is appropriate. “Expected” is a useful way to summarize what is projected, whereas “will” conveys certainty about the projection. See the traceable accounts regarding Key Message 11.1.
43	P19/L1-5	The statement on the effect of carbon fertilization and changes in climate is confusing. It is not clear whether the first sentence means that CO ₂ , temperature, and precipitation acting together reduce yields or whether each factor alone reduces yields. The second sentence states that high CO ₂ concentrations and longer growing seasons by themselves have beneficial effects. The Committee suggests clarifying the relationships among the driving variables and the combined effect.
44	P19/L13-17	The paragraph as written is fine. What is not addressed here or in Chapter 11 (Agriculture, Food Systems, and Rural Communities) is whether adaptation by the agriculture sector could offset the adverse impacts of climate change. Is it technologically possible or do we not know? Are there barriers to implementation of technological and managerial changes that would result in adaptation being less effective? Such information could be very informative to the agriculture sector.
45	P20/L5-9	The sentences describing how low-income households are more vulnerable to higher energy costs are true. The Overview should note, however, that annual energy expenditures are projected to decrease because reduced heating costs are projected to offset increased cooling costs (see Chapter 19 [Economics]).
46	P20/L27-31	There is an implication here that these extreme events and other changes are directly due to climate change. However, authors should make it clear that these events may have become more likely because of climate change, not that they were directly caused by climate change. Consider adding a sentence at the beginning indicating that no single event can be directly attributed to climate but that the odds of some events has increased due to climate change.
47	P20/L31-33	The text states that millions of internal migrants are “expected,” which we interpret to mean are projected. Chapter 19 (Economics) discusses migration but states that numbers cannot be projected. Chapters 28 (Southwest) and 26 (Southern Great Plains) raise the possibility of migration into the United States from Mexico but do not project numbers. The Committee cannot find discussion in the report on internal migration nor any projections of how many people would migrate. The Committee’s understanding is that while

		migration is quite possible it is difficult to project how many migrants there can be, where they come from, and where they go. The Committee suggests carefully reviewing the relevant chapters and revising statements on migration to reflect what is in those chapters. The Committee cautions against reporting specific projections largely because the field of migration projections from climate change is in a nascent stage and specific projections should be treated with caution.
48	P21-22/L26-3	The science suggests that climate change will cause more intense, but fewer hurricanes. This statement should be consistent with this.
49	P22/L10-14	The paragraph on adaptation of infrastructure is sound but, as noted above, it does not address whether adaptation has the potential to offset adverse impacts of climate change, or how expensive or feasible such measures may be. Infrastructure adaptation is often incremental. Since the report discusses the need for transformation, is the effectiveness of incremental adaptation limited, particularly under higher emissions scenarios?
50	P22/L13-14	Suggest adding “among other actions” to the end of this sentence.
51	P22/L24	The word “devastating” may not be appropriate for a scientific report.
52	P22/L25	The term “well-being” is vague. Perhaps it would be more focused to address the extent of health impacts from climate change across the country (i.e., whether the health of Americans is being adversely affected by climate change).
53	P23/L1-2	“Of families and communities across the country, with more people exposed to a compounding mix of health hazards, including.” Please add “increasing the odds of.”
54	P23/L8	Does the report support the statement that climate change harms everyone’s health?
55	P23/L14	Suggest “contexts” instead of “impacts.”
56	P24/L12	Recommend starting this section with the point that climate is not the only stressor on ecosystems: land-use, air, and water pollution are also occurring at the same time and adding stressors (Chapters 6 [Land Cover and Land-Use Change] and 7 [Forests]).
57	P24/L19-21	The Committee suggests phrasing this as a risk management matter (i.e., the risks of passing ecological tipping points increases with higher emissions).
58	P24/L23-24	“Many climate impacts, particularly changes in ocean conditions and extreme events, already threaten coastal, and aquatic, and marine ecosystems (Figure 1.10).” Include “increase in the odds for some extreme events.”
59	P25/L1-3	Is the projection about fish die-off tied to a particular scenario or scenarios? This is important to help readers understand how likely the outcome is and whether mitigation reduces the likelihood of the outcome.

60	P25/L21	The title of the section states “and abroad.” The Fifth National Climate Assessment (NCA5) focuses on impacts on the United States. Chapter 17 (Climate Effects on US International Interests) focuses on international impacts on US international interests and does not summarize international impacts (page 17-18, lines 19-20). Thus, it is not appropriate to have “and abroad” because international impacts are not a subject of NCA5.
61	P25/L25-26	The finding on projected international economic impacts is based on one study (Swiss Re, 2021) which was not published in a peer-reviewed journal and appears to be an extreme estimate. Chapter 19 (Economics) (page 19-12) finds that for each 1°F increase in average temperature, US gross domestic product (GDP) is projected (not “will”) be reduced by approximately 0.13 percent. Several citations are given. Since the latter comes from a chapter about economics rather than international impacts, the Committee suggests citing that projection instead of the international GDP projection.
62	P26/L9-15	Authors should mention justice concerns regarding mitigation and adaptation (i.e., that mitigation and adaptation are done in a way that does not adversely impact already overburdened communities).
63	P27/L1-2	A more accurate heading would be “Many regional economies and livelihoods....”
64	P27/L3-4	The sentence is technically correct (see comment above), but it does reflect the entire draft NCA5 report, which identifies some sectors and regions that are projected to have some benefits.
65	P27/L3-7	Please add a sentence or phrase here emphasizing that usually already overburdened communities suffer more.
66	P27/L18-22	The paragraph only mentions adverse impacts on Midwest agriculture and does not mention any positive impacts such as improved wheat yields (see Key Message 24.1, page 24-4, lines 10-11). The Committee recognizes that overall, US agriculture is projected to face losses. Chapter 1 (Overview) should reflect the breadth of findings on agriculture.
67	P27/L23-26	Suggest including a note about building out new energy technology. The Inflation Reduction Act (IRA) includes many changes in the tax credit system to build out a variety of energy sources and there are worker apprenticeship and vulnerable populations considerations built into the credits. This discussion is frequently omitted from the Chapter 1 (Overview) discussion of energy, and fossils fuels are compared repeatedly to renewables, which is not the full picture. Suggest: “...shift as the energy sector transforms toward more renewables and low carbon technologies, electrification of more sectors of the economy, and power infrastructure....”

68	P27/L27-29	The examples for outdoor industries are geographically limited and only focus on certain activities. Please refer to the Committee's comments on page 1-12, lines 1-2, on the broader recreation literature. Studies that have examined impacts on total recreation in the United States have estimated net increases in welfare and expenditures. This can be tempered by noting decreases in cold weather recreation and how sea-level rise, more intense storms, and fire can limit recreation gains and reduce it in some cases.
69	P28/L1-8	Figure 1.14: The Committee has comments on recreation in Chapters 1 (Overview) and 19 (Economics). Chapter 1 (Overview) points out limitations on recreation from extreme events and reduced cold weather activities such as skiing but does not address the effect of higher temperatures on warm weather recreation and whether a longer time period with warm weather will be offset by extreme events.
70	P28/L3-4	Figure 1.12: What is the citation for the statement that Colorado ski resorts have lost revenue of because of declining snowfall? Vail Resorts does not report declining revenues since 2019. ⁴ These years were affected by COVID-19, but revenues in 2022 were about 10 percent higher than 2019.
71	P28/L13-15	The Committee applauds the caution applied to projections of climate change on crime and domestic violence, mental health, and happiness. We also note that the literature on annual recreation impacts does not find there will be a reduction in overall recreational but most certainly a reduction in some aspects, such as skiing, and adverse impacts on many warm weather recreation activities from extreme events and fire.
72	P29/L13	The title should be "cultures, heritages, and traditions."
73	P29/L14-15	The language in the sentence is sweeping and the Committee questions whether it is fully supported by the draft NCA5 report. Is the language meant to imply that all community ties, pastimes, and landscapes are being threatened or some? Is the clause "Americans are losing the things that make them feel at home" appropriate for a scientific report?
74	P29/L24-26	The focus of the bullet is on cold weather recreation with no mention of how warm weather recreation can be affected. Even though the discussion is on what aspects of Americans' lives are being lost or threatened, by leaving out what could be benefits to warm weather recreation, the discussion is unbalanced.

⁴ See <https://www.macrotrends.net/stocks/charts/MTN/vail-resorts/revenue>.

75	P30/L1-13	The discussion on outdoor activities and particularly the analysis of implications for outdoor industry does not reflect the literature on climate change impacts on recreation. The discussion ignores that higher temperatures will lead to a longer season for outdoor recreation (see literature cited in comment on page 1-12, lines 1-2). The chapters cited do not address tourism across the country and Chapter 19 (Economics) does not cover tourism. The literature establishes that some aspects of tourism are projected to be adversely affected, but it does not find that all recreation or tourism will be reduced.
76	P31/L3-5	In the sentence beginning, “The extent of...” what is meant by “today?” Does this imply that decisions made “tomorrow” are ineffective or less effective? It is not clear that the draft NCA5 report has addressed effectiveness of timing of mitigation measures.
77	P31/L7-22	The Committee agrees that the more GHG emissions are reduced the more risks are reduced, but the statement is incomplete in that it does not address sequestration or removal and options to reduce radiative forcing. The Committee suggests using the term “net emissions” to include sequestration. Authors should cite Chapters 7 (Forests), 11 (Agriculture, Food Systems, and Rural Communities), and 32 (Mitigation).
78	P31/L24-28	Chapter 3 (Earth System Processes) discusses use of climate scenarios, and Chapter 1 (Overview) should cite the chapter.
79	P31/L29	Insert “emissions” before “scenarios” to clarify these are emissions scenarios.
80	P31/L29-31	The sentence beginning “This is due to...” is confusing. Chapter 32 (Mitigation) should also be listed as a source backing up the statements because it addresses infrastructure, economics, and policy.
81	P35/Figure 1.17	Suggest including the y-axis labels on the right graphs as well as the left.
82	P36-41/Section 5	Note that the general comments on Chapter 1 (Overview) in Chapter 3 of this report raise concerns about this section having many policy prescriptive statements. The content of many of these statements can be revised to be policy informative without appearing to be policy prescriptive.
83	P36/L2-7	The entire paragraph is policy prescriptive. The term “worst consequences” is unclear particularly regarding how much of a change in climate is associated with them. Does “avoided” mean they will not happen, they will be less severe, or the risks are reduced? Did the draft NCA5 report find that anything less than “large-scale” and “drastic” decarbonization of the economy will be ineffective? What about carbon sequestration or other options to reduce radiative forcing? The sentence on transformative mitigation and adaptation is policy prescriptive.
84	P36/L5	Would “near term” be more accurate than “immediate?”

85	P36/L9-10	The first sentence of the paragraph is policy prescriptive. Beyond that, does the draft NCA5 report analyze the timing of emissions reductions?
86	P36/L11	To be more accurate, the statement should say many options are “relatively cost effective.” Neither the statement nor the analysis addresses whether the benefits of the options are greater than the costs.
87	P38/L8	Suggest changing the title of the section to “net emissions.”
88	P38/L18-19	This statement does not reflect content in Chapters 5 (Energy Supply, Delivery, and Demand) and 32 (Mitigation). Low-carbon, hydrogen, and nuclear should also be included.
89	P38/L29-34	These sentences omit the challenges of grid stress, the need to build out distributed energy resources, zero-and low-carbon electricity sources, and resources needed to build out infrastructure to support the energy transition (i.e., critical minerals) (cite Chapter 5 [Energy Supply, Delivery, and Demand] and 32 [Mitigation]). Suggest updating the last sentence in the paragraph to read “recent legislation (IRA) has incentivized the deployment of low carbon, zero carbon, and renewable energy generation.”
90	P39/L1	While transformative adaptation can reduce unequal vulnerabilities it is not evident that it will automatically do so. As noted elsewhere, it is not difficult to think of transformative adaptations that could continue or even exacerbate unequal vulnerabilities. Such potential outcomes are discussed briefly on page 31-10, lines 24-26.
91	P39/L9-11	Is the issue that all transformative adaptation should meet these criteria to be considered or is it that to be just, transformative adaptation should meet these criteria? This could be considered policy prescriptive.
92	P39/L9-16	This is a very important paragraph that should be rewritten in language that broad audiences can understand.
93	P39/L18-24	It is not clear how the restoration of the watershed was transformative. Was it a result of the governance process that was used?
94	P40/L2-18	This section seems repetitive; if needed, these points could be made in other sections or shortened. The next section and other justice concerns could be expanded instead.
95	P40/L19	The section title is policy prescriptive because it implies a preference for a particular policy approach.

CHAPTER 2: CLIMATE TRENDS

#	Page/Line	Comment
1	P2-13/L20-24	Citations are missing for statements in this section.
2	P3/L15	Suggest not beginning a paragraph with a nebulous subject like “this.” What, specifically, has consequences for the United States?

3	P3/L16	Suggest replacing “this changing climate” with “climate change.”
4	P4/L12-13	The last sentence could be construed as policy prescriptive. The penultimate sentence is excellent, however, and would be a perfectly fine way to end the paragraph. Suggest removing the last sentence altogether.
5	P4/L17	Suggest replacing “even more warming” with “higher than average warming.”
6	P7/L5-9	Definition of aerosol optical depth (AOD) in the figure caption is welcome but suggest adding some context for the units. Is this a trend in AOD per year? Overall change in AOD during the period in question? How does the magnitude of the trend compare to the mean? Without the latter, it is not possible to know if the trend is impactful (i.e., is it 0.1% change or a 50% change?). It is not clear from the figure caption.
7	P11/L4-5	More support is needed for the statement that US sea-level is accelerating. Figure 2.5 shows trends, not acceleration. Appendix 4 shows a single sea-level curve for the United States—assuming the authors are referencing Figure A4.10—but it may be difficult for the general reader to ascertain acceleration in the curve. Suggest adding either a quadratic or trend lines pre- and post-1990 to Figure A4.10. Also suggest removing the reference to Figure 2.5 here, because it does not relate to acceleration.
8	P11/L9-12	Suggest adding the role of Pacific Ocean-atmosphere variability (i.e., Pacific Decadal Oscillation [PDO]) in suppressing rates of sea-level rise (SLR) along the west coast of North America (e.g., Bromirski et al., 2011; Moon et al., 2013).
9	P12/L25-37	Suggest connecting the statements in this paragraph to specific US regions and territories (e.g., changing Pacific cyclone tracks and El Niño-Southern Oscillation [ENSO] for US-Affiliated Pacific Islands [USAPI] and changes to hurricane frequency for the Southeast).
10	P13/L13-17	The last sentence in this section is out of place as this section is not about flooding and would be more relevant as the last sentence in the section of text on page 2-11.
11	P15/L27	Paleoclimate research has been very helpful in understanding the western US climate changes. It will be helpful to add some discussion with references on paleoclimate here.
12	P16/L14	It will be helpful to add a reference like Albano et al. (2022) that provides a more complete and newer assessment than Williams et al. (2020), including being continental US scale rather than Southwest limited and being based on multiple different data sources.
13	P17/L1-2	Is this Sweet et al. citation correct? The referenced report is about SLR scenarios.
14	P18/L31-35	The mixing of degrees Celsius and Fahrenheit in this paragraph is confusing. Suggest choosing one or providing both in all cases not just some cases.

15	P21/L17	Please add the data source: CMIP5 or CMIP6? It is not clear what LOCA2 means.
16	P22/L5	Please add the data source: CMIP5 or CMIP6? It is not clear what LOCA2 means.
17	P22/L7-10	It should be noted and referenced that the recent multidecadal drought in the Southwest United States is at least partially due to natural variability and not entirely due to human-driven climate change.
18	P25/L13	Missing the upper bound on the range “3 to ? billion.”
19	P27/L17-20	The word “likely” has a specific meaning in NCA5 in terms of probability (>66%). The values presented here appear to correspond to the entire range of scenarios from Low to High, which does not correspond to the likely range as it is defined for NCA5.
20	P27/L26	The tone of the sentence sounds too strong. Consider rephrasing.
21	P29/L2	“Nonlinearly” is likely not an accessible word for broad audiences.
22	P34/L1	The key message title here differs from the title elsewhere.

CHAPTER 3: EARTH SYSTEMS

#	Page/Line	Comment
1	P4/L2-3	This is the first line on land-use effects on climate: much of the land-use effects will be direct albedo modification, but this is not mentioned.
2	P5/L29-30	Please add caveats: this statement is only true in a few places (i.e., North America and Europe) where they analyzed data. There are no data in places we expect to see increases (e.g., Asia).
3	P10/L9-10	Is “sequencing” the wrong word? Longer than a decade? Projections longer than 2 days start getting quite uncertain.
4	P14/L3-4	Please try to indicate the proportion or be more specific.
5	P16/L1	The discussion of global warming levels warrants a new paragraph.
6	P17/L25	Perhaps use a more recent addition to the Shepherd (2016) “storyline” citation, which is all about how to construct/populate storyline scenarios (for attribution or otherwise), (e.g., Albano et al., 2022).
7	P18/L1	“Storms that might have been”: perhaps it is worthwhile to mention “pseudo-warming experiments” here, as it seems that this is one of the recent approaches to disentangling natural from climate change contributions in some individual events (e.g., Gutmann et al., 2018; Michaelis et al., 2022; Ullrich et al., 2018).
8	P18/L14-15	In addition to increased frequency and magnitude, “increases in duration” of various extreme events (heat waves and many storms) should be included here. In many settings, the duration can be deadly (in case of heat waves) or results in largest precipitation totals (e.g., Kossin, 2018; van Oldenborgh et al., 2018).

9	P19/L31	California is a great example of the final statement in this paragraph (e.g., Polade et al., 2017).
10	P19/L31-32	Please remove the “thus” as separate points which do not necessarily occur at the same time.
11	P19/L36	This is an important paragraph, but does not talk about all the implications, including making it harder to do detection and attribution studies.
12	P20/L3	Total vapor transport is a natural combination of both changes in total vapor content and the circulation changes discussed here and goes a long way toward simplifying the statement of conclusions. Lavers et al. (2015) would simplify the discussion.
13	P22/L11	Atmospheric water demand can change as well and could be discussed here (e.g., Albano et al., 2022; McEvoy et al., 2020).
14	P28/L31	Perhaps including in this chapter some of the changes in storm tracks impacting the west coast storms could be helpful and using more recent papers instead of Neelin et al. (2013).
15	P34/L23-28	The authors should concentrate on citing the evidence base, not discussing the scientists themselves. Replace “Scientists have known” with “Scientific studies show.”
16	P35/L1-6	This paragraph discusses topics that are not in this key message: should be moved or removed. Attribution is discussed later in the chapter.

CHAPTER 4: WATER

#	Page/Line	Comment
1	P3/L6-7	Suggest placing the first clause of this sentence at the end of the sentence for greater clarity. As written, it is unclear whether climate change is responsible for greater exposure and vulnerability, which is what the sentence is trying to convey. Suggested modification: “Climate change is increasing the frequency, of water-related disasters in the United States and causing greater exposure and vulnerability to these disasters.”
2	P3/L13-15	The statement about water security seemingly has nothing to do with the next sentence about water quality. It leaves the audiences to deduce the relation between climate impacts to water quality and water security. Suggest improved clarity in language and adding in-line descriptive and transitional language, for example: “Water security refers to the adequate supply of clean water, whereas water quality refers to the availability of clean water. Human-caused climate change is expected to directly impact the availability of clean water, which indirectly threatens the availability of that water for use by people and ecosystems.”
3	P3/Figure 4.1	This is an effective representation of year-by-year changes in the occurrence and kinds of billion-dollar disasters since 1980. Can a

		brief listing of (or more specific term for) what kinds of storms constitute the “severe storms” category be included in the caption? The audiences will be broader than the meteorology community.
4	P5/L5-7	The words “regulations and standards” would be more accurate as “policies, regulations, and formal agreements.”
5	P5/L14-16	This sentence is not accurate; it should mention climate change. It should read: “These and similar efforts are the first steps toward building resilient human and natural systems in the face of climate induced changes to the water cycle.”
6	P5/L18	“Human-caused climate change,” rather than just “climate change.”
7	P5/L20	Declaring that “many regions ... see more precipitation” seems problematic here, when even Figure 4.3 shows that fully a third of the country is projected to see less. A few words added could hand this pivotal projection (for this chapter) more informatively: “see more precipitation in the northern parts, and less precipitation in the southern parts.”
8	P5/L21	More precipitation does not always yield more floods. Floods depend on a lot of additional factors, like antecedent soil moisture, precipitation form (rain versus snow), and vegetation/land cover. For example, as stated in the caption of Figure 4.12, well less than half of recent flood increases can be attributed to increasing precipitation.
9	P5/L27-29	Suggest describing the water cycle and any natural variability. Then discuss climate change impacts to the water cycle. These topics are sometimes lumped together in the chapter.
10	P5/L30	This section on precipitation has no citations; please add some.
11	P6/L11-17	This section on evapotranspiration (ET) changes assumes audiences understand the how ET relates to climate change, but it likely will not. Suggest brief descriptions: How does ET relate to climate change? Explain to general audiences how climate change can influence ET. Explain in what regions will climate change cause ET to go up and in what regions will climate change cause ET to go down. When ET goes up/down is that good or bad? Why? This explanatory text could also be integrated into the caption text for Figure 4.4.
12	P7/L8-23	Some of the citations in this section detailing snow and glacier changes are quite old. Is there new literature looking at this?
13	P7/L11	These references regarding snow versus rain transitions are old. Several more recent studies have revisited and honed understanding of how this works (e.g., Harpold and Brooks, 2018; Harpold et al., 2017).
14	P8/L17	This projection of increasing soil moisture “in the northern US” is essentially diametrically at odds with Figure 4.6.
15	P9/L8-21	Are there regional differences in groundwater change expected due to climate change?
16	P9/L15	Are higher temperatures related to climate change? If so, make sure to say so.

17	P9/L15-20	The summary of projected western groundwater-recharge changes (i.e., “decreas[ing] natural recharge across much of the West,” stated without confidence level) is a key example of this kind of overbroad depiction of change and is directly contradicted by a key figure (6) in their primary citation (Niraula et al., 2017), which shows very different outcomes in different regions, time frames, and from different climate models. This conclusion is based on one cited research paper and based on one model analysis untested by other groups, so that confidence should be relatively modest, at present. Furthermore, it would be a breakthrough if this NCA5 report acknowledged that groundwater recharge varies temporally with important lessons for climate-change assessment from understanding and quantifying these variations.
18	P9/Figure 4.6	The projections of increased summer soil moisture over much of the Southwest here are a puzzle that should be discussed. The pattern also needs to be communicated to, and coordinated with, the authors of Chapter 28 (Southwest), who draw a different conclusion (projecting soil moisture declines there, even though their own soil moisture Figure 28.2a shows this same increase in soil moisture).
19	P10/L18	Streams dependent on glacial melt are expected to have increased flows in coming decades (as the ice melts) followed by flow declines later after the ice is essentially gone.
20	P11/Figure 4.8	This is a useful infographic indicating both the complexity of projecting future flood changes and the mechanisms that will determine those changes. Maintain tense alignment in all three text boxes (e.g., “Decreased flood magnitude...” should be listed for each bullet under “Decreases In Flood Activity” box rather than “Decreased flood magnitude...” and then “Decrease in magnitude”).
21	P14/Box 4.1	The material presented in this box very much follows the discussion (and even choice of figures) from Harpold et al. (2017). This article is also where the warm snow drought/dry snow drought nomenclature was formally developed and recommended. Thus, the citations included here should be adjusted accordingly.
22	P15/L4	It is not immediately clear what “the frontlines of climate change” are and this should be defined for broad audiences. This term is used throughout the report so this might be easily solved by adding the term to a glossary or index. Alternatively, a different term in the key message language could be used.
23	P15/Figure 4.12	Clarify whether precipitation change is due to climate change in the figure title and caption.
24	P15/Figure 4.12	This is an interesting and informative way to show recent trends in US flood damages. It would be useful to briefly list some of the “other” causes of flood damage (besides increased precipitation) in the caption, since this is not stated in the text (other than an allusion to increasing amount of impermeable surface, which is not the only other cause).

25	P16/L5	High precipitation routinely overwhelms many stormwater-sewer systems around the country, probably more than captured by “can.”
26	P16/L3-10	No mention is made of positive effects of floods on farmlands and floodplains (such as soil renewal and dissipation of flood impacts downstream). Including this observation would also provide an opportunity to mention corresponding reforms in US Army Corps of Engineers policy.
27	P16/L11	This text does not mention climate change until the fourth paragraph and instead seems to expect the audiences to infer that the discussion pertains to climate change. Suggest improving clarity and focus of language to focus on specific climate change impacts to drought.
28	P16/L19	“Megadroughts” are (historically) natural events. The point that megadroughts have happened many times in the natural past is neglected throughout this chapter, which makes for a dangerously one-sided presentation of, for example, developing conditions in the Colorado River basin.
29	P16/Figure 4.13	The caption says higher temperatures and human use can exacerbate or even cause drought. Please clarify whether this means higher human use of what resources (e.g., water, land). Also, should the last sentence be an “and” or an “and/or” rather than an “or” when discussing that drought can develop in a matter of weeks and/or last for decades?
30	P17/L4	Drought-driven streamflow (and lake level) declines also threaten cooling-water supplies for thermoelectric (traditional and nuclear power plants) systems, impacting many non-hydropower systems. Also correct this at page 4-18, line 10.
31	P17/L5	Discussion lacks mention of transportation impacts of droughts and floods along major rivers.
32	P17/L10	Consider replacing “insects” with “pests” to be more comprehensive.
33	P17/L14	If increased groundwater pumping is region specific, authors should note that detail in the text. The literature cited does not represent the United States broadly. Bloomfield (2019) is looking at groundwater in the United Kingdom; Hanson et al. (2012) is using a case study of California not looking at the United States broadly and discusses a method to assess how climate change could affect surface water and groundwater rise in highly developed agro-urban watersheds; and Scanlon et al. (2012) looks at the high plains and central valley of California and does not represent a nation-wide trend. What about other types of watersheds? What about other regions? The literature cited does not represent the United States broadly nor does it represent the very broad statement in the supporting text.
34	P17/L17	Increased pumping <i>can</i> increase land subsidence, not “does.” Land subsidence depends on a lot of factors that all have to be aligned for it to occur.
35	P17-18/L23-11	Consider mentioning tribal rights to water in the drought-stricken Colorado River basin that have yet to be quantified.

36	P18/L21	Duration of precipitation is also projected to increase (e.g., Gutmann et al., 2018; Kossin, 2018) in ways that will mimic or exacerbate the impacts of heavier precipitation.
37	P18/Figure 4.15	This is a graphically simple depiction of the disproportional distribution of flood damages projected over the next 30 years. It is an excellent addition to this key message and Box 4.2 that should be discussed in both.
38	P18-19/Box 4.2	This material dives relatedly into the topic of Key Message 4.2 by focusing on the specific case of Hurricane Katrina flooding and Houston. It should refer to Figure 4.15 where it notes “as with recent floods elsewhere” to drive home the representativeness of what this Katrina example indicates more broadly. It also needs to cite the corresponding regional chapter and should tie back to climate change at least briefly to be entirely clear that, whether or not Katrina was enhanced by climate change (and lots of attribution studies suggest it likely was), it is a good model of how disparities arise and play out.
39	P19/L11	What type of infrastructure is being discussed? Add text to improve clarity of language.
40	P19/L11-17	This is stated entirely in terms of impacts on tribes, which is accurate and well-motivated, but many of these impacts also apply to other disadvantaged, underserved communities elsewhere, which should be acknowledged.
41	P21/L10	Suggest explaining why uncertainty always factors into water planning.
42	P21/L20-21	Saying that water disputes are typically resolved using litigation is not quite accurate. It depends on the scope of the dispute and the disputing bodies. If two people, two states, two countries, or tribes versus other users there are actually a variety of ways disputes can be resolved. Additionally, the reference cited does not support this statement. Suggest deleting this sentence and adding the text suggested in the next comment.
43	P21/L21-23	This sentence is overly simplified, the references provided are not legal, and they do not discuss the entire body of law that applies to the Colorado River, which determines what allocation options are available for water rights holders. A more accurate sentence might say: “Climate change impacts to water supplies can result in competition, collaboration, or conflict. Tools may include litigation, administrative proceedings, treaty negotiations, compacts, and/ or cooperative agreements, among others. Under current severe drought conditions, water rights holders in the Colorado River basin, including Mexico, tribal nations, states, and other interested parties are struggling to adapt under the existing legal framework—one that was mistakenly based on the assumption of continued flows and on an above average historic estimate of total water available to apportion. While some of these efforts include tribes....” See suggested citation (Garofalo, 2019).

44	P21/L18-26	Suggest moving Figure 4.19 to under the discussion of the Colorado River here after line 26.
45	P21-22/Box 4.3	This material does a nice, brief job of illustrating how interjurisdictional cooperation can succeed, but a word or two more about how climate change will be addressed under the new management plan, or at least how the expected success of the plan will likely be impacted by climate change, would make it much more relevant to this chapter and report. The corresponding regional chapter should also be cited.
46	P22/Figure 4.18	The caption should address the level of scientific understanding arrow across the bottom of the image.
47	P23/L17	It is worth noting, here and elsewhere in this chapter, that natural variability of storms and droughts (and temperatures) are projected to increase in magnitude (e.g., IPCC, 2021a).
48	P24/Figure 4.19	The figure is important and yet left until the end of the chapter and then not fully discussed. This is where the issue of how much of the recent western megadrought is climate change and where the issue of how much normal climate variability can and will mask and/or interact with coming climate changes is finally given some illustration. Having this figure appear earlier in the chapter and having what it shows described there in detail would be a major improvement to the chapter as a whole.
49	P26/L26-36	This projection is largely missing from the key messages, replaced instead with descriptions of a recent paper. Albano et al. (2022) provides useful multi-dataset comparisons and analyses of evaporative demand trends over the contiguous United States and might be considered in this traceable account.
50	P26/L26	Consider mentioning the status of the long-standing discussions of measured pan evaporation trends (or lack thereof) in this context in this traceable account (given the strong assertion regarding future evaporative demands here).
51	P26/L31	Neither changes nor variability in recharge have been well quantified or projected.
52	P26/L33	The advancement of snowmelt timing is also projected to increase overall (annual) streamflow totals in many areas (e.g., Ban and Lettenmaier, 2022; Barnhart et al., 2016).
53	P27/L5	This section makes many strong and concise statements but needs citations to support those statements regarding uncertainties and gaps.
54	P27/L6	This chapter regarding water should be more careful about not ascribing most uncertainties to precipitation; rising temperatures (as has been acknowledged earlier in this chapter) are projected to have major impacts on future water. Better to drop the “especially precipitation” here. There will still be significant uncertainties about how much warming will occur and quantitatively how much that warming will impact water in which ways.

55	P27/L28	This is a good acknowledgment of real uncertainties as to how complicated the pathways to eventual streamflow outcomes will be. It might be worth also acknowledging that the more recent literature has been turning up “second-order influences” beyond just precipitation and temperature impacts, including factors like humidity (e.g., Harpold and Brooks, 2018; Harpold et al., 2017).
56	P27/L37-38	See Albano et al. (2022), which has resolved many disagreements through a multi-dataset comparison of the various trends and non-trends.
57	P28/L6	This discussion regarding groundwater pumpage impacts is focused entirely on irrigation pumping and ignores the equally impactful and widespread issue of urban pumpage.
58	P28/L17	Consider adding “outside of the most heavily groundwater-developed areas” to the end of this sentence. There are a lot of groundwater level data in places that are dealing with overdrafts; there is much less data collected where climate is a primary driver. There is also very little monitoring directed at tracking recharge variations.
59	P28/L22	This characterization of precipitation as only increasing is misleading and does not agree with the chapter’s own maps. The traceable account for Key Message 4.1 does not touch on the water quality issues raised in Figure 4.2.
60	P28/L27	Some mention of confidence and likelihoods regarding water quality changes is needed.
61	P28/L33	Given that this sentence starts out talking about natural conditions (and presumably variability), this statement that extreme events will increase amounts to a non sequitur (not an incorrect statement, but it does not follow from the “evidence” of the first half of the sentence).
62	P29/L20	Add “water quality” to this list of research needs.
63	P29/L21	The “Major Uncertainties and Gaps” discussion neglects to mention the extreme limitations of our knowledge regarding water quality impacts of these extremes. It states, “There is uncertainty about...” and neglects to categorize how much uncertainty.
64	P29/L25	The “Description of Confidence and Likelihood” discussion on lines 27-28 makes a weak case for (and nearly contradicts) the Key Message 4.2 conclusion that these systems cannot adapt quickly. Mostly this paragraph is a restatement of the claims of Key Message 4.2 rather than a description of how confidence/likelihood were assigned.
65	P30/L23-24	This same assertion that a lack of downscaled projections is the limiting factor was made, with no more evidence here than in Key Message 4.3. Either here or there, more citations supporting this assertion are needed.
66	P30/L34	Some literature support for this assertion that adaptation efforts are proceeding slower than climate change would be extremely useful; not disputing it but would very much like to have that evidence at hand.

67	P31-42	None of the citations for the figures from University of Colorado are in the bibliography.
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CHAPTER 5: ENERGY SUPPLY, DELIVERY, AND DEMAND

#	Page/Line	Comment
1	P3/L1-18	The introduction does a great job defining words in text, for instance adaptation and the changing risk profile.
2	P3/L23-25	The last sentence of the key message should be reorganized to have active voice and more clearly establish that the extreme precipitation, extreme temperatures, sea-level rise, and more intense storms, droughts, and wildfires are likely to damage energy infrastructure and disrupt energy system operations. Using active voice in sentences with confidence and likelihood ratings helps the rating make more sense.
3	P3/L29-30	Mention permafrost impacts on distribution and energy consumers. These are discussed on page 5-7, lines 3-7, in terms of production.
4	P5/L1-3	Add language to improve clarity to this sentence: “and are projected to be impacted by changes in solar irradiance.”
5	P5/L10-31	The discussion about electricity generation and water availability omits discussion of how some low- and zero-carbon technologies use more, in some cases much more water. Thus, the demand for water could increase with the deployment of some low- and zero-carbon electricity and energy generation processes. Citations are included in the chapter but CCUS, small modular nuclear reactors, and hydrogen can all increase water demands.
6	P5/L15-16	The connection of dam-removal-to-protect-vulnerable-species to climate change is not clearly articulated and should be clarified.
7	P5-6/L17-7	Suggest adding brief discussion in first paragraph of this section on oil and gas delivery that discusses what oil and gas are used for besides electricity so that even in a “transitioned” world, their development, use, and delivery is relevant.
8	P5/L21	Use of the term “risks” in this case does not seem to conform to recommendations of the IPCC on risk language.
9	P5/L27-29	For the sentence discussing operations relying on reservoir storage, clarify whether this is particularly difficult in some regions of the United States as compared to others.
10	P6/L1	Is this only true of aging assets?
11	P6/L9-10	Subsidence and landslides—specifically climate change driven?
12	P7/L12	Suggest using “as well as” instead of “and” in line 12 between consumption and peak demand patterns.
13	P7/Figure 5.2 and L8-13	Suggest integrating Figure 5.2 into text discussing electricity demand by discussing timelines depicted in the figure in the text.
14	P8/L1	Clarify that this is a projection.

15	P8/L7-24	Suggest offsetting the explanatory clause in the second sentence of the key message with commas: “Compounding and cascading hazards related to energy systems and additional stressors, such as cyberthreats and pandemics, create....”
16	P8/L33-34	Suggest cross-referencing the hydrogen box in Chapter 32 (Mitigation).
17	P9/L1-7 and 8-12	Suggest describing why some energy supply chains are more susceptible to supply chain disruptions. Suggest more clarity when discussing the critical mineral (CM) supply chain disruptions. Are the regions in the United States or other countries? What geopolitical and environmental factors influence how these materials are extracted, used, and recycled. This discussion omits the key points that the United States is reliant on processing facilities in other countries and at the same time is reliant on CMs to successfully transition to a net-zero economy. While the United States has lots of CM resources and can mine them, often the separations and processing facilities are not sited here due to environmental concerns, thus the United States is reliant on a more global supply chain to source the processed minerals, or the end-use products made with processed CMs. This might be a good place to mention both the Trump and Biden Executive Orders on critical minerals. This comment is also included in Key Message 32.4. So, if this ends up being covered there, suggest cross-referencing Chapter 32 (Mitigation) here.
18	P9/L20-30	Please clarify the connection to climate change.
19	P9/L31	It might be helpful to add to the discussion of vulnerable communities the impacts of transitioning to a different electricity profile and different energy generation sources to energy sector workers who will not be trained to work in different technologies and may resist the movement to low- and zero-carbon renewable energy.
20	P9/L31	It might be valuable to note that overburdened communities are likely to disproportionately benefit from decarbonization by way of reduced ground, water, and air pollution and potentially by the and increased resilience and addition of jobs from renewable energy.
21	P9/L32	If this sentence applies to climate impacts to energy systems, add that to the sentence: “Overburdened communities are disproportionately affected by climate impacts to energy systems.”
22	P11/L9ff	This should start several steps earlier (i.e., “higher winter temperatures” lead to “insects survive winter” leads to “infestations damage and kill trees” leads to “increased tinder,” etc.).
23	P12/L1	The word “on” in the key message title seems out of place. Suggest “Progress continues toward enhancing” or “Progress continues to enhance” or suggest rewording the title.
24	P12/L15-17	Be careful with interchanging the words “mitigation” and “adaptation.” They are sometimes used interchangeably in this chapter and in this report and this will create confusion for general audiences. Here, it seems the activities for the oil industry are

		adaptive to climate impacts to infrastructure, not mitigation efforts. Suggest removing “mitigation” from this paragraph altogether since it is discussing adaptation measures to boost resiliency of energy systems and infrastructure.
25	P12-13/L22-15	The two topics—planning for energy system resilience and hardening energy systems to reduce vulnerabilities to climate change—could be combined into one shorter section. Both discuss modeling advances, for instance.
26	P14/L7	Suggest defining Internet of Things devices in the text. Or just use “smart devices, like internet connected appliances and cameras” or something similar.
27	P16/L10-13	Suggest explaining what types of costs for solar and wind decreased and why this was.
28	P17/L12-16	Suggest detailing where these demonstration projects are located to improve reader convertibility with the topics.
29	P17-18/L17-18	Suggest including a description of the IRA and new two-tiered tax credit scheme that emphasizes worker protections and vulnerable communities for developers and generators to qualify for the full amount of credit. Suggest including a discussion of energy-sector workers who are vulnerable to the energy transition changes to their livelihoods.
30	P20/L14-15	Expressing confidence that frequency and intensity of extreme events will increase seems to be a broader statement of confidence than generally accepted in the professional literature since it seems to encompass all types of extreme events and cover all locations in the United States (and presumably territories).

CHAPTER 6: LAND COVER AND LAND-USE CHANGE

#	Page/Line	Comment
1	P7/L12-13	Not all wildfires are climate driven; suggest making the sentence clear that in some places there is an increase in wildfire risk due to climate change.
2	P7/L18-19	These threats also come from land-use as well, so including other stressors in this discussion would add to the complexity but also highlight the risk to these systems.
3	P7/L20	Add something here on Great Lakes shore erosion.
4	P8/L23-24	Revise to make this a complete sentence.
5	P10/L7-8	This is not consistent with Chapter 7 (Forests)—the sink is created by growing stock and harvest products. It also contradicts the citation to Pugh et al. unless the CO ₂ effect on the regrowth areas is also attributed.
6	P10/L10-11	A significant land sink is not attributed to abandonment of agriculture. Domke et al. (2021) and EPA (2022) do not document this.

		Agriculture abandonment is a relatively small sink compared to forests remaining forests and urban areas.
7	P11/L32-33	Harvest and management reduce ecosystems resilience? Is this true as a general comprehensive statement? Some forest management will in fact be required such as assisted regeneration.
8	P12/L33-37	This is a confusing discussion and should be revised for clarity.
9	P13/L1-2	In other places it is the opposite; this is not a generalizable example.
10	P22/L27-28	There is substantial uncertainty in both biogeochemical and biophysical impacts of land-use and land cover change. This implies only the biophysical are uncertain, while the impacts on the carbon cycle end soils especially of different land-use management techniques is not well understood.

CHAPTER 7: FORESTS

#	Page/Line	Comment
1	P3/L1	The introduction could set up the key messages more. Perhaps it would be nice to see some introductory synopsis of what the message is and how we know it with confidence.
2	P3/L5	The introduction lists the goods and services that forests provide, including “spiritual renewal” but does not mention the Indigenous cultural values of forests and this seems important to mention up front. These cultural values are, on the other hand, covered well under Key Message 7.2.
3	P4/L3-6	It would be interesting to see the frequency distribution of the map above (i.e., the distribution of number of years by region and nationally).
4	P5/L5-8	Should include a statement that these were driven by climate change factors not natural factors. Is the increase due to climate change and is that documented? There is no reference to Domke et al. (2022), nor is it readily found in the literature. Domke et al. (2021) is there. If this is reference to an update, it is very important and should be accurately referenced.
5	P5/L17	Could be better worded. See comments in Chapter 2.
6	P5/L18-19	This sentence is described in the introduction, not Key Message 7.1; is this the right place for this sentence? It is actually covered more in the text for Key Message 7.2; perhaps move there?
7	P5/L24-26	This statement should have an example.
8	P6/L6	An example is needed of “effects.”
9	P6/L11	Make sure readers know prescribed fire is intentional.
10	P6/L19-20	What is a national scale; does this mean consistently and widespread across the United States?
11	P6/L21-23	For example, cite Andela et al. (2017), which shows that globally fire burn area is going down, perhaps because of land management/use.

12	P8/L11	This interpretation is incorrect: “western tree species are migrating poleward through seedling success (Sharma et al. 2021).” The paper said, “Whereas fecundity may be primed to lead tree migration in the West, local climate complexity that comes with rugged relief affects how migration potential should be interpreted. The combination of dry climates and fast climate change in the intermountain West explains fecundity and recruitment vectors in Fig. 3 E and F that point toward the cool, moist regional climates of the Northwest. However, for migration, these cool-moist conditions are locally found at higher elevations. The regional centroids average over this variation contributed by steep terrain.”
13	P13/L16	Domke et al. (2022) is not referenced, nor can it readily be found in the literature.
14	P14/L4-9	Sources should be specified. This figure needs to be reconciled with the national GHG inventory, EPA (2022) or EPA (2021). The sinks estimate here are not consistent with Domke et al. (2021) nor the national GHG inventory. The caption needs to better describe the figure. What is NEE and other acronyms? Explain that harvested wood product (HWP) “transfers” are a sink when the areas regrow, otherwise it is a sink that does not have emissions associated with it which is different. Is NEE from the regrowth? Or from new lands converted, or CO ₂ fertilization and productivity?
15	P14/L12	Change to “...are a critical component of the hydrological system and the provision of clean water.” We do not think “forests produce water” is the intended meaning.
16	P15/L1-3	State that this is an example of how climate change affects forest changes and in turn other impacts, in this case water flow and flooding.
17	P16/L24-25	Figure 7.10 does not show adaptation practices. It shows land ownership.
18	P21/L6-7	This statement needs a citation.
19	P22/L11-14	The reference to Sharma et al. may have been misstated. Check if it actually shows evidence of migration, or evidence to suggest migration.
21	P22/L15	See more literature on this (e.g., Novick et al. [2022]).

CHAPTER 8: ECOSYSTEMS, ECOSYSTEM SERVICES, AND BIODIVERSITY

#	Page/Line	Comment
1	P5/L1	It would be useful to emphasize in caption as well as text that “transforming into new systems” means “transforming into new, often degraded systems less able to provide ecosystem services.”
2	P5/L13	Clarify if the “delayed harvest of plants” in the Northern Great Plains means “delayed harvest of crops.” Also, explain the significance of

		“loss of rivercane,” other biodiversity examples are more familiar or obvious ties to ecosystem services.
3	P7/L20	Consider including Ibanez et al. (2022) as another possible citation on multiple stressors.
4	P8/L8-10	Consider replacing words like “transformative” and “stable, which have a positive effect with “degraded” or “ecosystem collapse.”
5	P10/L9	Avoid the phrase “is complex” and replace it with a more specific statement. Ecologists often use this phrase when talking about ecosystems even though what is really meant is that there are surprises, or that there are direct and indirect effects of climate change that act together on ecosystem functions (e.g., pollinator webs, food webs).
6	P11/L8	The “Monitoring Transformations” subsection could, through minor rewording, more clearly convey that these monitoring networks (Figure 8.8) have been established in recent decades in direct response to global change. The National Ecological Observatory Network (NEON) may have fully come online since NCA4. It is worth emphasizing this because otherwise it sounds as if ecologists have always monitored, when in fact this is a recent development.
7	P13/L14	This paragraph and associated Figure 8.9 are confusing because the figure exemplifies coral reef adaptation, but there is no mention in the text of corals. Instead, authors used Tetlin National Wildlife Refuge as an example, which is a great example, but it is not clear if they used the Resist-Accept-Direct (RAD) framework. The Committee suggests doing some minor rewording to address this disconnect.
8	P14/L19	Avoid using the term “complex” and replace it with something more specific.
9	P17/L13	Change “Box 8.2” to “Box 8.1” (there is no Box 8.1).
10	P19/L1	Box 8.2 is a nice example, but a few more words about why large-bodied species are vulnerable to extinction and climate change would be useful—it is the second time body size has been mentioned.
11	P20/L1	Should “disease risk,” which focuses on diseases of animals and their vectors, also include plant disease (fungal and other plant pathogens) that affect natural ecosystems (e.g., Sudden Oak Death) and crops? A few possible references for discussing plant disease are Burdon and Zhan (2020) and Juroszek et al. (2020).
12	P20/L12	Table 8.1 is informative, but the Committee suggests adding a column identifying where this risk occurs in the United States.
13	P22/L7	The Committee appreciates that the statement about invasives that have declined in response to climate change is so well referenced but suggests adding a few examples into the text. The focus on the subsection is on invasives expanding due to climate change, so it is difficult to get a sense of the relative importance of these two groups.
14	P29/L16	Could emphasize not just “buy-in” from local already vulnerable communities, but solutions that are designed and led by those communities (i.e., “co-produced” with other actors).

15	P33/L27-32	The climate envelope models are used in nuanced ways to assess future climate change vulnerability. They predict habitat distribution and often use other environmental predictors in addition to climate (e.g., soil, topography, vegetation cover). There are procedures for incorporating dispersal rates (i.e., can organisms occupy shifting habitat), identifying and limiting confidence in predictions to novel environments, and focusing on habitat suitability changes within the current range (exposure). What this approach does not address is plasticity and adaptation.
16	P33/L35-37	It is not necessarily useful to think of range shifts as being driven by extreme weather events. Extreme events are likely to affect population processes via mortality and so forth, especially in combination with other global change stressors. Other modeling approaches are needed to forecast ecological changes on the order of decades, and those frameworks are being used.
17	General	An additional reference, Warren et al. (2018), could be added on range shifts (global).
18	General	The following papers on natural climate solutions could be good additional references: Griscom et al. (2017), Law et al. (2021, 2022), and Novick et al. (2022).

CHAPTER 9: COASTAL EFFECTS

#	Page/Line	Comment
1	P4/L2-4	This opening statement conflates regional and global mean change, as well as absolute and relative sea-level in confusing ways. (1) Stating that sea levels are rising and accelerating globally gives the impression that this is true everywhere, but it is not. There are many locations where relative sea-level rise in the United States is falling (e.g., some locations in Alaska) and/or not accelerating (e.g., most of the US west coast). It would be more accurate to say, “Global average sea-level is rising and accelerating due to thermal expansion...” (2) The inclusion of vertical land motion here is tricky because it is the only reference to relative sea-level in this statement. It does not represent variations in the thermal expansion and addition of water mass that are referenced in the first part of the statement. It is also a highly local (not regional) effect. It would be best to edit the second part of this opening sentence to be more specific about where the named variations occur, such as “...with variations occurring along local and regional coastlines due to...”
2	P4/L5	“Accelerating, rising” is awkward phrasing.
3	P4/L6-7	Authors should choose between feet in figure and inches in text. Reading and interpreting the text will be easier if the same units used in the text are also used in the figures.

4	P4/L10	The phrase “on average 3-7 days per year” is too vague. Is this 3-7 days in at least one location across the whole country? Or 3-7 days at every location across the country? If the latter, it is unclear how this is a useful statistic given the huge amount of spread between locations around the United States.
5	P4/L17	Missing dash in range of SLR in meters provided in the parenthetical.
6	P4/L28-29	Suggest the reference to Figure 9.2 be moved to the previous sentence, which is what the figure shows. The figure does not pertain to differences across emissions scenarios, which is what the sentence describes.
7	P4/L28-29	Include the emissions scenario the numbers in the paragraph are based on.
8	P5/L5-9	Including the idea that coastal landscapes evolve across a range of timescales due a range of climate-driven and natural phenomena is great. It would be good to provide similar context for the previous section on SLR and high tide flooding, stating that sea-level (e.g., ENSO) and tides (e.g., nodal cycle, harbor dredging) also evolve on a range of time scales due to a range of natural and climate-driven reasons.
9	P19/L26-30	A major source of uncertainty prior to 2050 is the impact of natural climate variability on the projections.
10	P20/L28-37	This paragraph needs references.

CHAPTER 10: OCEANS AND MARINE RESOURCES

#	Page/Line	Comment
1	P3/L2	Suggest beginning the sentence with the subject of the chapter, i.e., “Oceans span tropical, temperate, and polar regions; support diverse and productive marine ecosystems; and provide innumerable benefits to the US.”
2	P3/L2-9	Defining and making clear that NCA5 assesses a huge region of the United States, not just the continental US, is well done here, but a simple reference to Figure 10.1 would emphasize this point.
3	P4/L8	Specify higher emissions scenarios.
4	P4/L1-11	Key Message 10.1: there are no likelihood statements provided. However, these statements may have quantitative evidence to support them, and if so, should include likelihood statements (this is also true for Key Message 10.2 and Key Message 10.3).
5	P5/L28-29	Consider adding ENSO events to the list of impactful extreme events for marine ecosystems. The last one was devastating to coral reefs throughout the Pacific.
6	P6/L1-6	Overall Figure 10.1 is a good figure, but please expand the figure caption to explain all the symbols and where the information comes from.
7	P6/L13	Suggest specifying very high emissions scenario.

8	P7/L6-8	This is an important point that could be elevated to part of the key message.
9	P7/L9	Suggest making a referenced statement somewhere in this box stating whether the severity and/or frequency of such marine heat waves is expected to increase with ongoing and future climate change.
10	P8/L1-7	Figures 10.2, 10.4, and 10.5: the figure captions should contain all the information to explain the figure as well as the citations so that the figure is self-contained.
11	P10/L17	Specify emissions scenarios.
12	P12/L10	Suggest either using a less technical term than “extirpation” or defining the term in the text.
13	P13/L4-13	Consider mentioning wave energy conversion, a nascent technology, which may be particularly useful for the west coast, Hawai‘i, and USAPI, even though it is mentioned on page 10-15, line 15.
14	P15/L4-6	Here is a good place to highlight the need for continued investment and expansion of the National Ocean Observing System.
15	P18/L13-14	The Front Matter rubric emphasizes evidence and publications, not data. It would be more accurate to remove “data” from the statement here.
16	P18/L23-32	Indigenous island communities are highly impacted by ocean change (see Chapters 23 and 30) and should be highlighted here.

CHAPTER 11: AGRICULTURE, FOOD SYSTEMS, AND RURAL COMMUNITIES

#	Page/Line	Comment
		None

CHAPTER 12: BUILT ENVIRONMENT, URBAN SYSTEMS, AND CITIES

#	Page/Line	Comment
1	P1/L1	Ensure chapter title is consistent with built environment definition, and if not revise the title.
2	P3/L2	Recommend stronger first sentence.
3	P3/L3	Use of urban residents’ livelihoods automatically sends a tone that this chapter is only about the urban built environment. Is that what the authors intended?
4	P3/L7	Recommend stronger first sentence, such as “recent science shows how climate change is having cascading and compounding effects on the built environment.”
5	P3/L12	Suggest cross-referencing Chapters 5 (Energy Supply, Delivery, and Demand), 13 (Transportation), and 18 (Sector Interactions, Multiple Stressors, and Complex Systems).

6	P3/L14	Suggest changing “historically disadvantaged communities” to a term consistent with other chapters. Other terminology suggestions include overburdened, highly impacted, or historically underinvested.
7	P3/L23-25	Recommend stronger first sentence that is more accessible.
8	P3/L29	Suggest changing “historically disadvantaged communities” to a term consistent with other chapters. Other terminology suggestions include overburdened, highly impacted, or historically underinvested.
9	P3/L36-37	Suggest increasing readability for broader audiences.
10	P4/L3	Largest 10 cities plus the top 5 percent of suburbs: consider having Figure 12.1 actually show those 10 cities and the suburbs with labels using data from 2018 rather than the map shown (2015).
11	P4/L16-18	Opportunity to increase readability for broader audiences.
12	P5/L1	Figure 12.2: Suggest explaining and contextualizing the importance of the data shown. It is also difficult to tell if there are clear differences in the maps that are visible with the maps being that small. It appears that there is a small change to states like Montana, Wyoming, and Utah. Perhaps focusing on areas that are predicted to have the greatest change would be more meaningful.
13	P5/L13	Appreciate the reference to Chapter 6 (Land Cover and Land-Use Change) but consider also including the title of the chapters when being referenced. This is consistent with cross-referencing done in other chapters.
14	P8/L9	Suggest adding something like: “If mitigation and adaptation measures are not deployed quickly and sufficiently then urban areas will continue to be significant drivers of climate change....”
15	P8/L17	Suggest modifying Key Message 12.2 title to be a statement.
16	P8/L19	Suggest replacing “existing loads” with more accessible language.
17	P8/L22	Suggest replacing “infrastructure deficits” with more accessible language.
18	P9/L6	“Linking extreme events to climate change is critical for assessing, disclosing, and managing risk to urban systems.” is an important point that is just left hanging at the end of this paragraph. Suggest incorporating it into the introduction or key message and expanding on why it is important for the built environment.
19	P10/L15	Suggest referencing health impacts broadly instead of using “diseases such as asthma.”
20	P11/L12	Suggest adding a specific example about the disproportionate burden on populations. For instance, Houston’s urban heat island mapping showed a 17-degree difference between two neighborhoods on the same time and same day.
21	P12/L7	Consider including this point in the introduction or at the beginning of this key message.
22	P12/L14	While this section talks about the reduced “life expectancy of heating, air-conditioning, ventilation, and filtration systems as well as

		road pavements and tarmac surfaces,” it does not mention the impact of people, especially overburdened and vulnerable people.
23	P12/L18	Another use of “loading” that should be clarified for broader audiences.
24	P12/L28	Perhaps an opportunity to highlight some of what is being done, such as LEED for Cities, and updates to building and zoning codes.
25	P12/L29	Very general statement. Which systems? Perhaps an opportunity to link to other chapters.
26	P12/L32	Caution how “local beliefs about climate change” is being used; perhaps local action or inaction (based on beliefs) would be another way to phrase this statement.
27	P12/L34	Perhaps provide one or more examples for how to increase awareness, or better yet, action, and provide an example of what has worked.
28	P12/L38	Suggest using more accessible language.
29	P13/L4	Add “climate” before “risks.”
30	P14/L1	Suggest using a more informative statement for the key message title, such as: “Climate Action Opportunities for Cities.”
31	P14/L11	Confirm the 2014 reference is needed; has this system been updated in the last 8 years? It appears to be a dated reference.
32	P14/L14	Consider referencing BRIC in this section.
33	P14/L16	Suggest providing a quantitative percentage of plans that did not explicitly address climate risks. If this information is not clear, consider rewording.
34	P14/L18	Suggest adding “and for climate adaptation and resilience.” This statement is incomplete without this additional information as this section is covering both mitigation and adaptation.
35	P15/L2	Suggest defining/describing what a co-benefit is here.
36	P16/L11	“Nature based solutions” and “green infrastructure” are both mentioned here, and Figure 12.2 references “natural infrastructure.” Suggest using consistent (and the most common) language.
37	P17/L6	Replace “struggle” with “seek.”
38	P17/L13	Tribal communities or tribal nations?
39	P17/L17	Capitalize Chief Resilience Officers and note that some states have appointed Chief Resilience Officers.
40	P17/L18	Capitalize Chief Heat Officers and include Chief Sustainability Officers here too.
41	P18/L3	Clarify if the communities referenced here are “rural.”
42	P18/L7	Clarify if taxes are declining or is revenue declining.
43	P18/L12	Give examples of states that are exceptions.
44	P18/L13	Which cities? This chapter should have more specific examples and less generalities.
45	P18/L15	Is it capacity, or ability, due to constraints including capacity?
46	P18/L29	Suggest changing the first sentence to read, “Local urban planning efforts incorporating climate actions show varying progress....”

47	P18/L37	Provide examples of what is working.
48	P19/L3	Consider reworking this paragraph for readability.
49	P20/L3	Consider “residents’” interests instead of “citizens’.”
50	P22/L2	Consider explaining why cities are underreporting GHG emissions.
51	P27/L5	Consider resident support instead of citizen support.

CHAPTER 13: TRANSPORTATION

#	Page/Line	Comment
1	P1/L2-5	Text can be added to define mobility in addition to the current language on the transportation network.
2	P1/L11-14	Text can be added on planning for future transport needs for people.
3	P1/L16-19	An opportunity to add text on emerging mobility options.
4	P3/L14	Are risk assessment and long-term costs the key to equitable investments? Lines 20-21 provide concrete suggestions: “Inclusive decision making and data-informed processes.”
5	P3/L24	Replace “remains” with “is.” Not long ago (2016), the power sector was the largest sector. ⁵
6	P3/L25	Perhaps replace “industry” with “sector.”
7	P3/L32	Limiting global warming requires a path toward “achieving net-zero.”
8	P4/L10	Remove the White House citation.
9	P6/L4-6	Remove, “Cells with few or no bullets...” and complete a more comprehensive literature review.
10	P6/L1-6	Table 13.1 caption uses term “bullets” in line 5. However, the table does not include bullets.
11	P8/L5	Spell out “DOT” acronym since this is its first use.
12	P9/L9	Perhaps replace “greater” with “increasing” or quantify what it is greater than.
13	P10/L13-14	Perhaps replace the first “expected” since the sentence currently reads as “expected to perform well beyond expected.”
14	P13/L3	For most scientists, “significantly” would imply some test and confidence. Replace with a less loaded word.
15	P15/L1-6	This paragraph, which continues from the previous page, lacks citations.
16	P15/L27-28	Mention “non-combustion electricity generation.” It would be helpful to have a sentence devoted to the implications of fuel cell technology for transport.
17	P19/L18	This is the only time “rural” was mentioned in the entire chapter.
18	P19/L23	Spell out “TSU” acronym since this is its first use.
19	P19/L34	Replace “...from other authors” to “...from other chapters.”
20	P21/L32-36	Replace semicolons with commas or break up the sentence.

⁵ See <https://afdc.energy.gov/data/10802>.

CHAPTER 14: AIR QUALITY

#	Page/Line	Comment
1	P3/L35-36	Give examples of human-caused emissions.
2	P4/L25	Remove the period in “warming (KM 14.5)., is...”
3	P5/L4	Remove the underscore in “concentrations in the Northeast_.”
4	P5/L8-11	The caption for Figure 14.1 needs to be self-contained, and have citations.
5	P6/L1-2	Font size of figure title changes.
6	P6/L4-5	The figure captions should describe everything in the figure and explain all the acronyms. It looks quite busy: consider converting this to a mean and a range for each color instead?
7	P7/L34	Remove “and” in “problems, and worse outcomes for birth...”
8	P8/L5-6	Climate change could increase the odds of wildfires, although land conversion is likely to decrease the land available for wildfires, so it may not be so certain that activity will increase. Perhaps modify to “...the chance of wildfires in many regions will increase.”
9	P9/L3-5	Figure 14.3 caption should describe what is being shown: are these model- or observation-based? The grey versus the colored dots? Figure captions should be self-contained.
10	P18/L15-22	Figure 14.10 is not very clear and seems unnecessarily busy. Perhaps just showing the range of values would be clearer.
11	P18/L19	Spelling error in “...(in 2020 US dollars).”
12	P23/L21-34	This paragraph is missing citations: please include appropriate citations. Additionally, there was no previous citation to the epidemiology and toxicology studies that are referenced again here.
13	P26/L34	Add period between “change Conclusions.”

CHAPTER 15: HUMAN HEALTH

#	Page/Line	Comment
1	P3/L16-18	This key message needs a confidence rating after the first sentence.
2	P4/L10	Suggest using a dash instead of a comma.
3	P5/L1-4	These two sentences could benefit from more specific details or examples. Is the second sentence referring to just the west or the entire United States?
4	P5/L7-9	Suggest linking wildfire smoke to air quality first then associating it with impacts, and suggest defining cardiovascular-, cerebrovascular-, and respiratory-related health issues in line or providing examples of each.
5	P5/L16	Clarify if increased rabies exposure referring to human exposure or animal exposure. If not to humans, please clarify the link to increased animal exposure to rabies and human risk as the tick-borne disease section does in line 36 on the same page.

6	P5/L25	Suggest defining “vector.”
7	P6/L12	Suggest making the key the same color code as the images on the map.
8	P6/L19-20	This section is about both food and water; therefore, the first sentence should include water as well. Suggested text: “Climate change negatively impacts food security, nutrition, water security, and water quality, which harms health, particularly for communities.”
9	P7/L23	Is the word “relatives” intended to be a different word? Otherwise, consider clarifying the meaning of “fauna relatives.”
10	P7/L27	This sentence is missing a citation.
11	P8/L13	If possible, provide a more recent reference for this sentence.
12	P10/L3-4	The first sentence in the key message needs a confidence rating.
13	P10/L17	“BIPOC” and “low-wealth communities” may be fine words here, but the language to define specific vulnerable populations should be consistent across chapters in the report. As the language is now, many chapters use different terms to define similar populations. Suggest conformity and consistency across chapters.
14	P10/L25-27	Suggest listing the six climate-related hazards in the caption of Figure 15.4.
15	P11/L29-33	Suggest referencing Chapter 16 (Tribes and Indigenous Peoples) for these two sentences.
16	P11/L30-31	It is not necessarily clear what “on the frontlines of climate change” means. Suggest defining in-line.
17	P12/L13	Suggest defining “redlining” inline and given that this term is used throughout the report it may also be included in a glossary.
18	P12/L17-21	Consider explaining why Black and Latinx communities are more likely to live in areas with high air-pollution levels.
19	P12/L24-27	Does the use of “women” here refer to all women? Additionally, clarify what populations women are being compared to when stating that they are more likely to live in poverty.
20	P13/L14	Describe why or how the discriminatory beliefs impact care.
21	P13/L15-25	In the Figure 15.5 caption, specify what the underlying socioeconomic and demographic factors are. What does the sentence about a seemingly decreasing trend mean? Instead of “That would explain...” specify what “that” is. The first four sentences in this caption are unclear and unspecific.
22	P14/L6	Suggest a different word than “mainstream.” Consider also revising these sentences to have consistent tenses and reduce wordiness; they are confusing as written. A possible rewording could be “Proactive and continuous risk-management is critical to human health and well-being, particularly to protect at risk groups and health care facilities. Integrated approaches emphasize health in policies for food, infrastructure, water, and sanitation.”
23	P15/L2	Suggest clarifying why is there a growing “at risk” population and who this population includes.

24	P15/L1-31	This section is missing the climate connection; audiences need that connection to be made overtly.
25	P15/L32-37	This section is missing the climate connection; audiences need that connection to be made overtly.
26	P16/L3-12	This section is missing the climate connection; audiences need that connection to be made overtly.
27	P17/L13-24	This section is missing the climate connection; audiences need that connection to be made overtly.

CHAPTER 16: TRIBES AND INDIGENOUS PEOPLES

#	Page/Line	Comment
1	P3/L1-12	The introduction would benefit from more text before the images that take up almost two full pages.
2	P4/L12	Suggest ending the current sentence with a connection to Figure 16.3: "...strategies for adaptation to those changes which includes a holistic worldview."
3	P6/L3	Suggest "legal systems" rather than "legal environments."
4	P6/L23	Add the word "climate" in to replace "the" so that it reads "for the heightened severity of climate disruption."
5	P6/L25	Omit the word "their."
6	P7/L8-9	Suggest reordering to reflect the order of the key message as written and add energy if kept in this key message.
7	P8/L4	Remove the period between "barriers" and "(Figure 16.4."
8	P9/L1-23	This section on COVID-19 should reference the Focus on COVID-19 and Climate Change. If looking for an area to slim down, this paragraph is quite long and could be shortened.
9	P10/L8-11	This holding did not occur in a vacuum; it is based on the evolving US tribal law and policy (here assimilation) from the 18th to the 20th century that influenced tribal actions. Suggest clarifying this in text to reflect this distinction: "Due to the evolution of colonial policies and US tribal law from the 18th century to present day, and the influence those laws and policies had on Indigenous actions, some Indigenous peoples face intricate land-based jurisdictional circumstances today that prevent recovery of their historically occupied territory. For example, the US Supreme Court's holding in <i>Carcieri v. Salazar</i> (2009) prohibited contemporary land restoration for certain Indigenous peoples that historically acted on colonialist laws and policies."
10	P10/L11-12	Please add transition sentence between first paragraph to the second paragraph under "relocation."
11	P10/L25	Do these opportunities (a range of options) currently exist or is the use of the word "opportunities" to imply a change or possibility for progress? The options or changes could be explained in more detail.

12	P13/L5-8	This sentence would benefit from an explanation why funding is not often distributed in “ways” (typo, not “was”) that Indigenous peoples can access.
13	P13/L15-16	Suggest providing examples of coordinated infrastructure projects that mutually support one another.
14	P13/L16	Please correct to be “Indigenous peoples’.”
15	P14/L19	“Knowledge” can be both singular and plural: suggest removing the “s” from “knowledges.”
16	P15/L3	The term “peoples” is more commonly used than “persons.”
17	P15/L15	Please correct to be “Bureau of Indian Affairs’.”
18	P16/L26	Suggest adding the research term, “land-based healing incitive” (Johnson-Jennings et al., 2020; Redvers, 2020).
19	P20/L28-38	This is a great overview and could possibly be summarized or placed into introduction of chapter.

CHAPTER 17: CLIMATE EFFECTS ON US INTERNATIONAL INTERESTS

#	Page/Line	Comment
1	P3/L6-9	The final sentence of the first paragraph of the introduction is policy prescriptive and should be reworded slightly.
2	P3/L16-17	The final sentence is too vague to be meaningful and should be revised.
3	P3/L16-25	Suggest removing this paragraph as it does not seem relevant to the chapter topic.
4	P4/L22-24	Last sentence of Key Message 17.1 is policy prescriptive and should be reworded slightly.
5	P6/L3	In Figure 17.1, the bullet “Climate resilience” under the heading “Climate resilience” is redundant and should be removed.
6	P12/L10-11	The projection reported in the sentence is not present in the referenced source.
7	P12/L25-26	Rising sea levels should not be listed as “less well quantified.” Sea-level rise is well observed and quantified.
8	P12/L26-27	Increasing average temperatures are not the concern. Global average warming is a useful indicator of climate change, but the impacts to health and agriculture will be regionally specific due to shifting patterns of temperature and precipitation.
9	P16/L2	The discussion suffers with combining observations and projections in one sentence (e.g., poverty rates).
10	P21/L21	Suggest using a different word than “significant,” as it is an undefined term.

CHAPTER 18: SECTOR INTERACTIONS, MULTIPLE STRESSORS, AND COMPLEX SYSTEMS

#	Page/Line	Comment
1	P6/L18-22	Is this an example of polarization or systematic discrimination?
2	P6/L25-28	Not clear what this has to do with complex systems.
3	P13/L4-16	Paragraph has no citations.
4	P13/L11-16	Sentence filled with jargon.
5	P13/L19-26	Does the deep uncertainty to the complexity of the systems or the scenarios?
6	P14/L6-8	Sentence is true but can price signals exacerbate unequal impacts?
7	P16-17/L26-10	Traceable account for Key Message 18.1: The Committee questions the ranking of high confidence in this emerging field. Many of the findings are based on one study, Reed et al. (2022), which is not consistent with the definition of high confidence provided in the Front Matter.

CHAPTER 19: ECONOMICS

#	Page/Line	Comment
1	P4/L3	Lipton et al. (2018) is about migraines. From the title of the publication, it is not clear it has anything to do with climate change.
2	P4/L16	The literature is filled with studies on the economic impact of climate change on agriculture and only one citation is given here. Does the new work on agriculture completely negate older studies (e.g., Rosenzweig and Parry, 1994)?
3	P6/Table 19.2	“Student Learning” row: The Park et al. study finds that the adverse impact can be offset by use of air conditioning.
4	P9/Figure 19.1	The figure is hard to read and might be easier to read if it is displayed in a landscape format.
5	P18/L27-28	The literature on climate change and violence is thin and needs a lot more analysis to establish a reasonable level of confidence.
6	P18/L24-27	Judicial decisions, political turnover, etc. seems to be somewhat speculative.
7	P21/L11-33	Consider including uncertainties about societal changes (e.g., population, income, and technology).
8	P24/L3-17	Consider including adaptation.

CHAPTER 20: SOCIAL SYSTEMS AND JUSTICE

#	Page/Line	Comment
1	P4/Figure 20.1	Consider clarifying the purpose of this figure. Is the purpose to introduce three dimensions of justice for assessment analysis?
2	P8/L15	Add a period after “(2017)....”

3	P9/Figure 20.2	This figure does not provide essential information and could be described in one to three sentences.
4	P10/L8	Remove the period between “society. (Oreskes....”
5	P13/Figure 20.3	If this figure intends to demonstrate that social systems influence migration and that climate change may exacerbate but that planned relocation could increase just outcomes, the message is not well understood through this Bronfenbrenner ecological framework and more recent frameworks have been presented in the literature.
6	P14/L11	Add a period after “...2022).”
7	P14/L22	Use lowercase “h” in “Hired.”
8	P15/L17	Remove “a” in the “right to a fair....”
9	P15/L19	Add a comma between “oil gas.”
10	P17/L18	Suggest “Indigenous knowledge” instead of “Indigenous knowledges.”
11	P18/L11	Replace “such” with “human.”
12	P21/L30	Italicize “high confidence” for consistency.
13	P23/L31	Add “a” between “identify [a] research gap” and remove “research.”
14	P26/L8-9	Add “is” between “Much of that literature [is] also based....”

CHAPTER 21: NORTHEAST

#	Page/Line	Comment
1	P4/L18	Suggest using more recent projections if possible, and the statement could benefit from some people-focused context
2	P4/L27	Suggest expanding this discussion. The Northeast is heating faster than most regions of North America and extreme heat events cause more deaths each year than all other extreme weather events combined. This should be reflected in a more balanced summary of extreme precipitation and extreme heat impacts.
3	P4/L31	Social impacts are suggested but there is little mention of social impacts afterward.
4	P4/L34	Suggest using the term “hurricane” instead use of “cyclone,” based on the NOAA definition: “Hurricanes, typhoons, and cyclones are actually all the same type of storm, but have different names based on where they form. In the North Atlantic and central and eastern North Pacific, these storms are called “hurricanes.” In the western North Pacific, they are called “typhoons” and in the South Pacific and Indian Ocean, they are called “cyclones.” ⁶
5	P4/L36	Suggest “projected” rather than “expected.” This is a numerical projection and is probably based on a specific scenario which should be mentioned in the text.

⁶ Tropical cyclones are rare in the South Atlantic: <https://www.noaa.gov/education/resource-collections/weather-atmosphere>.

6	P5/L1	Increased nighttime temperatures also have significant implications for public health.
7	P5/L11	“Pluvial” should be defined parenthetically as “fluvial” is in line 18.
8	P5/L16-17	Needs a reference.
9	P6/L27-39	The paragraph is not specific to the Northeast region.
10	P6/L30	Cite Chapters 14 (Air Quality) and 15 (Human Health).
11	P8/L12	Suggest using “climate change” rather than “warming” because the sentence includes discussion of acidification.
12	P12/L30-38	The discussion of oxygen loss lacks explanation for general audiences and introduces related concepts (added nutrient load) without showing the connection.
13	P14/L14	The term “mitigation” is used in the context of adaptation as mitigation of impacts.
14	P14/L38	Based on racial discrimination is an important omission. Redlining is an important example of structural racism that has many present-day ramifications that have increased vulnerability to climate impacts.
15	P15/L6-17	Suggest noting implications for morbidity/mortality as well.
16	P16/L10-13	These lines present an opportunity to identify connections between important equity-related issues (e.g., air quality, urban areas, redlining, environmental justice).
17	P16/L13	“Reasons for the regional differences are unclear.” Please see literature on redlining and urban heat islands as well as air quality and environmental justice literature.
18	P16/L18	Perhaps “genital and urinary” rather than “genitourinary.”
19	P16/L23-33	Important to integrate the idea of a just transition here with broad implications not only for energy insecure populations but also for impacts to fossil fuel-dependent livelihoods and communities particularly in West Virginia.
20	P17/L22-23	Suggest adding “structural, political, and socioeconomic.”
21	P17/L33	Suggest adding “and burdens” so the sentence reads “... benefits and burdens...”
22	P18/L17-20	The sentence could be interpreted as being policy prescriptive. Alternative wording could be “In response to the announcement of intended withdrawal from the Paris Agreement in 2017 (the withdrawal had to wait 3 years), states, municipalities, tribes, and businesses....”
23	P26/L5	Suggest adding “households” to communities and businesses (there are a number of state-level incentives for household-level mitigation).
24	P27/L3	Suggest giving context on the Federal Emergency Management Agency (FEMA) flood map underestimation of risk.
25	P28-29/L26-19	Lack of well-defined metrics is another important obstacle for private-sector investment.
26	P29/L14	Cites “USA facts 2021” as the only source for the paragraph.

27	P32/L5-7	The discussion on research gaps regarding Key Message 21.2 mentions “multiple sources, especially farmers...” regarding droughts and high moisture. This appears to be introducing new evidence and is not cited. Recommend moving this to the text on Key Message 21.2.
28	P34/L6-14	An additional question is whether jurisdictions will be able to overcome non-financial barriers to adaptation (since finance is covered in Key Message 21.5).

CHAPTER 22: SOUTHEAST

#	Page/Line	Comment
1	P3/L2	The word “eons” is too technical. Consider rephrasing.
2	P3/L8	The word “animus” is too technical. Consider rephrasing.
3	P3/L11	The word “chattel” is too technical. Consider rephrasing.
4	P4/L12	Suggest including research on Ida or any of the major storms more recent than Katrina.
5	P9/L25	Please specify what “the region” represents.
6	P11/L9	Suggest also including North Carolina (Cherokee).
7	P11/L26-27	Change to present tense.

CHAPTER 23: US CARRIBEAN

#	Page/Line	Comment
		None

CHAPTER 24: MIDWEST

#	Page/Line	Comment
1	P3/L26	Wording choice. Once something is “built” it is “aging.” Perhaps cite the median age of infrastructure here?
2	P4/L16	There is no likelihood statement.
3	P4/L23	Annually may be used incorrectly. Suggest clarifying by stating that “annual precipitation has increased,” not that “it increased annually.”
4	P5/L3-7	It is not clear that the left panel is properly explained and related to the others.
5	P8/L18	Please change to “crop insurance losses continue.”
6	P10/L8, 11	There is no likelihood statement.
7	P15/L9	There is no likelihood statement.
8	P15/L32-33	This sentence leaves the reader wondering why this difference.
9	P16/L18-19	Suggest clarifying this logic. Certainly, other regions have higher population.

10	P19/L3-5	This diagram shows the annual values, from which one can infer the change. Suggest removing first two words.
11	P20/L15-19	This sentence (“Sufficient...”) borders on tautology. Perhaps “more” are needed but that begs the question how much more. Perhaps the chapter authors can be more specific here. Twice as many? Or perhaps the sentence can say that Centers for Disease Control and Prevention (CDC) suggests a model of how increases in resources correlates with improved outcomes.
12	P20/L29	There is no likelihood statement.
13	P20/L30	This fails to mention the electric grid, one of three sectors mentioned in the key message first sentence.
14	P20/L32	“...are in need of repair.” Can this be quantified? What fraction? What dollar value? Or provide some other sense of the magnitude of the problem.
15	P21/L3	“Recent grades” assumes the reader knows what is being graded; please rephrase.
16	P21/L19	“...high (A1B) and very high (A2)” The chapter authors should consider how to mix Special Report on Emissions Scenarios (SRES) and later scenario generations, so the reader does not get confused or overwhelmed.
17	P23/L14	Does this imply that a return period of 1 year signifies an extreme event? Also, given the non-stationarity, should chapter authors not be encouraging the use of exceedance probability language?
18	P25/L31-34	This suggests an interesting challenge. Is there any assertion that this small percent increase poses a problem? Is the annual value really the most helpful one to cite?
19	P27/L19	Is the type of aquifer the most important information about the groundwater system to convey? Perhaps the status of the groundwater system would be more pertinent in this report. Given the topics discussed in the text, a map of what percent of water resources comes from groundwater may be more pertinent. Also use only or mark the Midwest boundaries.
20	P28/L24	“Precipitation is expected to increase...” on the order of 1 percent according to the key message.
21	P29/L8	Suggest citing literature that demonstrates change versus variability.
22	P30/L7	Change “impact of” to “impact on.”

CHAPTER 25: NORTHERN GREAT PLAINS

#	Page/Line	Comment
1	P4/L1-3	Suggest defining the region; which states are included? Add some context for the region.
2	P4/L2-3	The sentence could be written about any region.
3	P4/L7-8	Suggest splitting this sentence into two sentences.

4	P4/L26-27	A region diversifying could be a lot of different things—for example, economic diversification; suggest “experiencing population diversification” or “becoming more culturally diverse.”
5	P5/L14-15	“Challenges” is used twice in this sentence; suggest using “changes” the second time the word is used.
6	P6/L15-16	This language (days then nights in parentheses) is confusing; suggest clarifying in text.
7	P6/L17-19	Suggest clarity in language by inserting introductory sentence: “The region has experienced less very cold days (defined as a maximum temperature of 0°F or lower) than the historic average (defined as ...) for the past few decades. For instance, there have been less very cold days than the long-term average in Montana since 1985, in....”
8	P6/L22-26	Insert “resources” after “on groundwater.” Suggest describing whether this is in the whole Northern Great Plains (NGP) region or just some states? Suggest citation of Siirila-Woodburn et al. (2021).
9	P9/L15	Suggest mentioning the states that are headwater states for the Colorado River basin.
10	P12/L18-24	Spiritual health is mentioned in the key message language and not in the supporting text. Please incorporate spiritual health into supporting text or remove from key message language.
11	P12/L26-27	Rephrase with active voice to remove passive voice: “Literature recognizes a spectrum of...”
12	P12/L31	Note that the Burke and Yazd studies are about national mental health risks, not specifically about the NGP. This is not the only place in the chapter where national studies are cited to for a statement about the NGP region. Please ensure that citations to literature discussing national trends are represented that way in the supporting text.
13	P13/L18-19	Is there any more recent literature on West Nile virus or vector-borne diseases in the region than 2014? Check Chapter 15 (Human Health).
14	P14/L5-8	Suggest defining nutrient load to incorporate the volume of the nutrient, passing through a single location, over a set period of time rather than just the volume. Is there more recent literature on this than 2014-2015?
15	P15/L4-23	Suggest renaming “loss of biodiversity” to “compound biodiversity impacts of climate events” to mirror earlier section discussing “compound health impacts of climate events.”
16	P18/L11-20	This section (three paragraphs) is unclear. The example is Texas, but then discusses outages in the NGP region. Were there power outages in NGP states due to Texas strains on the grid? Suggest revising to improve clarity and indicate the relationship to NGP region. Move last sentence up. Use active voice where possible. A rewrite could be something like this: “Climate change impacts and mitigation efforts are expected to increase energy demand across North America. Higher summer temperatures and heatwaves are expected to increase energy demand across the country, while higher winter temperatures

and fewer cold snaps are expected to reduce energy demand for heating in the Northern Great Plains. Increased energy demands from outside the Northern Great Plains will place demands on regional energy resources and electricity supply. Climate change will also stress energy infrastructure (e.g., rail, pipelines, distribution lines, transmission lines). Energy infrastructure is vulnerable to climate extremes. For instance, the power outages that resulted from the 2021 extreme cold event in Texas illustrate the importance and connection between demand, supply, and distribution across the US during extreme weather events.”

17	P18/L21-37	Add in transition phrases and sentences; this section reads rather choppy. Discuss the expected impacts of energy-sector changes to energy-sector jobs.
18	P20/L19	Offset “and exacerbating existing” with commas.
19	P20/L27	Rather than contextualize this as “renewable and nonrenewable” suggest “shifts in energy demand, production, and policy will change land-use needs for low and zero carbon energy infrastructure and development” to improve consistency with other chapters in the report (Chapters 5 [Energy Supply, Delivery, and Demand] and 32 [Mitigation]).
20	P21/L11	Since there is some discussion on mitigation, the section heading should be changed to state that it covers barriers to mitigation and adaptation.
21	P21/L15-16	It is not accurate to say this region discourages a transition and economic diversification. It is accurate to say there is resistance to turning completely away from fossil resources entirely. Suggest citation of Righetti et al. (2021).
22	P21/L18-19	This paper cited does not discuss water regulations and rights and this is not accurate without more clarification. What water regulations and rights are the chapter authors referring to here? Please clarify.
23	P22/L4-11	Integrate with energy discussions in Chapters 5 (Energy Supply, Delivery, and Demand) and 32 (Mitigation). This chapter could be from a different report with only categorization of “renewables” versus “non-renewables” and that categorization oversimplifies the issues. See discussion of other low- and zero-carbon technologies in other chapters: Chapter 32 (Key Message 32.4); labor section on page 29 (Key Message 32.2); Low-carbon fuels needed for some transport and industry applications; and Chapter 5 page 5-17. Nuclear, innovated low-, negative-, and zero-carbon solutions, increased production of low-carbon electricity including nuclear as well as fossil fuel electricity with CCUS.
24	P23/L10	This section omits discussion about the transition period between now and when the nation can be more fully reliant on renewables. The IRA reflects this with funding mechanisms for industry and commercial build out. Suggest more inclusive discussion of this

		transition period and the IRA support for many different types of energy development to better align with other chapters in the report (see comment above).
25	P23/L19-21	Nuclear also requires significant water for cooling; hydrogen does as well for production. Biofuels do use significant water for irrigation and for cooling if burned for electricity. Water use within a state is controlled by state law; water use for water that crosses state lines will be impacted by various federal and state legal mechanisms and can be quite complex.
26	P23/L25-26	Clarify if the planting of low-input tall grasses is already happening or should happen.
27	P23/L34-35	Drawbacks are not considered here. Depending on how used, e.g., if biofuels are burned for electricity production, a significant amount of water is still needed for cooling, just like fossils.
28	P24/L2	Please add the state the prairie pothole region is in.
29	P28/L16-28	Without a definition, the term “prior appropriation” is not likely to be well understood by broad audiences. Prior appropriation affords a right to use (not own) water. Put in simplified terms, the first person to put water to a beneficial use has the right to continue to use that water and if their use does not continue, neither does the water right. Most western states have codified the prior appropriation doctrine into statutes that define beneficial use, prioritize certain uses, and administer water rights through a permitting system that specifies administrative and or court processes necessary to modify water rights. In line 18, it would be more accurate to say the “ability to acquire water rights” rather than the “reallocation” because, legally, the water right would need to be sold or abandoned or enlarged, which all have different impacts on priority. When discussing water rights under the Colorado River Compact (CRC) then allocation is the correct word, but the CRC is not discussed until the next sentence. The phrase “turning water users off” in line 28 is not accurate, though it is “puny.” Suggest removing first half of sentence. Start sentence with “Different approaches....”
30	P28/L32-34	Please provide some examples of drought planning and improving ranch resilience.
31	P29/L8-9	The sentence reads as being policy prescriptive but can be easily revised to be policy informative, for example, “In response to flooding, improved monitoring was instituted....”
32	P30/L33-36	This sentence should mention public lands.
33	P32/L12	With the image above, it is hard to tell what “this work” is referencing—the image in Figure 25.10 or the previous text? Citing to the figure and moving the image to after all of the text in this section might make more sense.

CHAPTER 26: SOUTHERN GREAT PLAINS

#	Page/Line	Comment
1	P6/L11-13	Is this estimate for the whole nation or just for this region? The statement needs clarification.
2	P33/L13-14	The statement about faith-based organizations “praying for those who suffer” is inappropriate for NCA5 and should be removed from this sentence.

CHAPTER 27: NORTHWEST

#	Page/Line	Comment
1	P4/L6-8	Give example of damage in Washington and Oregon (i.e., “...as witnessed by [x] in Washington and Oregon...”).
2	P6/L3	Should be “Table 27.1.”
3	P7/L1	Suggest key message title be more of a statement: “Frontline Communities Affected Most by Climate Impacts.”
4	P7/L19	Remove “are” in “While are many types of...”
5	P9/L8	Suggest “community resilience” instead of “community resiliency.”
6	P9/L16	Suggest chapter references include the chapter title, consistent with other chapters.
7	P9/L22	Suggest tribes and Indigenous communities be included in the recommended glossary. Also suggest “both on and off reservations” is not needed and may not be inclusive of all tribal experiences in the way the chapter authors desire.
8	P9/L31	Suggest managed retreat language be as inclusive as possible and consistently used throughout all chapters. Consider any possible linkages to Chapter 9 (Coastal Effects).
9	P11/L11	Consider using “wildfire” instead of “fire.”
10	P12/L27	Consider using more accessible language for “extirpations.”
11	P13/L9	Seems like there is a missing word after “endangered.”
12	P14/L6	Suggest title be a statement, not a label. May want to include salmon.
13	P15/L25	Should be “increased.”
14	P16/L7	Suggest key message title be a statement: “Climate Changes Impacts on Economies and Livelihoods.”
15	P16/L14	Suggest referencing Chapter 11(Agriculture, Food Systems, and Rural Communities).
16	P16/L16	Add citation.
17	P18/L1	Suggest referencing Chapter 9 (Coastal Effects).
18	P18/L13	Suggest referencing Chapter 7 (Forest).
19	P18/L14	Remove “‘s” from “Northwest’s.”
20	P19/L22	Suggest title be more of a statement.
21	P20/L15	Suggest key message title be a statement. Also, currently this section is focused on water, transportation, and energy only. Suggest “Built Infrastructure” is too broad of a title for the current content. Authors

		should limit title to “Climate Impacts on Infrastructure Systems,” or expand the content that follows.
22	P20/L17	Key Message 27.1 includes housing; however, housing is not referenced below. Suggest including housing below (preferred) or removing housing from the key message.
23	P20/L25	Suggest providing more focus by saying infrastructure systems are threatened.
24	P21/L8	Add citation.
25	P24/L8	Suggest Box 27.4 be assessed to determine if this is necessary or if there is a way to better integrate or connect with a number of other boxes and the Focus On... Feature on wildfire.
26	P24/L28	If kept, include chapter title in reference.
27	P24/L34	If kept, include chapter title in reference.
28	P25/L6	If kept, include chapter title in reference.
29	P25/L9	Suggest key message title be more of a statement.
30	P25/L16	“Climate resilience” instead of “Climate resiliency.”
31	P26/L3	Spell out “BIPOC” since first time using this acronym or replace with “people of color” to be more consistent with language used throughout the chapter.
32	P26/L4	Should be “additional.”
33	P26/L14-16	Suggest mentioning PM standard to help reader gauge significance of 95 micrograms.
34	P28/L1	Remove “and” in “preparedness for and disasters...”
35	P28/L20	Suggest “Address Inequities” instead of “Bridge Inequities.”
36	P29/L20	Spell out “BLM” acronym to avoid ambiguity.
37	P30/L15	Suggest more accessible language here (e.g., “Northwest Environmental Sense of Place”).
38	P32/L6	Should be “medicinal plants.”
39	P34/L5-6	Add citation.
40	P38/L11	Should be “adaptation.”
41	P39/L6	Add space between “Government” and “2021.”
42	P40/L36	Convention is to say, “Indigenous knowledges.”
43	P41/L16	Statement “...that the region” seems incomplete.
44	P42/L12	Should be “impacts on [not of] tribal...”
45	P42/L26	Replace “is” with “are.”

CHAPTER 28: SOUTHWEST

#	Page/Line	Comment
1	P3/L11	Should sea-level rise be included in this list of impacts? It has been going on for many decades.
2	P4/L12	The population of the Southwest is strongly urbanized, but the region/landscape is notable for its vast rural and wild areas, sparsely populated overall.

3	P6/L1	Walton et al. (2017) is worth including here.
4	P6/Figure 28.2a	Any notions why soil moisture is shown increasing across interior California and Nevada here, despite other expectations projected in Chapter 3 (Earth System Processes)?
5	P7/L11	This projection of decreasing rainfall is only supported by a couple of studies and is likely to be very geographically variable (e.g., see Figure 6 in Niraulta et al. (2017)—the source for this statement in Chapter 4 [Water]—which shows a lot of place-to -place, model-to-model, differences in recharge outcomes).
6	P7/L16	Pumping “can cause” land subsidence but does not always and does not everywhere even in the Central Valley. There are drawdown thresholds that have to be crossed before subsidence begins.
7	P7/L31	No nature-based options listed?
8	P10/L1	Marine species compositions and geographic distributions. The arrival of new species far from their historical ranges is generally the most public-obvious change in this regard.
9	P10/L16	No citation. Is this from Chapter 10 (Oceans and Marine Resources) of the draft NCA5 report or someplace else?
10	P11/L10	Is “fishers” the correct word here?
11	P11/L15-16 and 30-31	Notably more reference to nature-based/nature-informed solutions here than in Key Message 28.1.
12	P12/L6	Saltwater intrusion changing groundwater quality (especially) and tables.
13	P13/L3	The Delta is not shown in these maps. The easternmost water body shown in upper panels is Suisun Bay, just below the mouth of the Delta.
14	P14/L8-9	In contradiction to the assertion here, Chapter 3 (Earth System Processes) (Key Message 3.12) notes and cites literature that frost hazards from “false springs” increase in current projections. Please revise to acknowledge, correct, or coordinate the assumption here with that finding.
15	P15/L16	Consider adding “forestry” to this list of vulnerable producers. Forestry is not generally considered agricultural, but it fits in among these dryland working lands in a way that is not discussed anywhere else in this chapter (notably not under Key Message 28.5).
16	P16/L14	This discussion focuses strictly on managing farmed fields but neglects the problems that will have to be managed on the increasing fallowed fields—distinct but of equal regional importance. ⁷
17	P17/L7	These programs require a lot of foreknowledge of what outcomes are desired. Is this a place to mention potential for maladaptations sticking to current insurance goals and programs past their useful era?

⁷ See <https://calmatters.org/commentary/2022/08/drought-requires-new-strategies-for-managing-cropland> and <https://www.ppic.org/publication/land-transitions-and-dust-in-the-san-joaquin-valley>.

18	P17/L37-38	The economic and livelihood impacts of the 2012-2016 California drought have proved more complex than might be expected at first glance (e.g., far less agricultural-economic impact overall); please consider incorporating perspectives from recent studies, like Medellín-Azuara et al. (2016).
19	P18/L23	Is California intentionally left off this list? Is this just a study-design aspect of the cited article or is California simply not like these others?
20	P19/L30	Is there any other epoch that provides numbers of hospitalizations to compare this 2018-2020 number to?
21	P19/L33	Consider adding pre-natal, natal, and neo-natal outcomes to this list (e.g., Amjad et al., 2021).
22	P19/L38	The term “cocci” should be used instead of Valley Fever because the World Health Organization and CDC are increasingly moving away from geographic stigmatizing names (e.g., COVID-19). It is an illness that often goes unrecognized until someone is ill, which can mask the geography of the disease. The 100-year projections are for cocci to become far more widespread at the end of the century, ⁸ so that the name Valley Fever will be even less appropriate; this projection would also be good to mention here.
23	P20/L9	The sudden appearance of SSP5-8.5 here is out of place compared to the more frequent use of “extreme emissions” and other scenario descriptors elsewhere in the report and chapter.
24	P22/L4	There is notably little white in the interior Southwest of these maps; but also, notably little land in many of those interior areas (much of Nevada, New Mexico, Utah, and Colorado) that already has few if any intensively harvested agricultural lands.
25	P23/L14	Is “immigrants apprehended” an accepted sampling/metric of the origins of migrants into the Southwest in general?
26	P23/L18	Should “loss of financial resources/livelihoods” be included in this list of drivers?
27	P24/L2	Financial and political constraints?
28	P24/L8	Where is the private sector in all of this?
29	P24/L29	Some long-term context on the role of wildfires in Southwest landscapes and livelihoods would be useful to set the stage for the list of recent events here.
30	P25/L13	Change “is” to “has also been.”
31	P25/L13	Mudslides “and debris flows.”
32	P25/L15	It would be worthwhile noting that climate change is projected to make these “heavy rains” heavier (cite Chapters 2 [Climate Trends] and/or 3 [Earth System Processes]). Although Murray et al. (2021) presumably focuses on coastal communities, this risk is in no way limited to coastal settings. See also Cordeira et al. (2019).
33	P25/L26	Houses “and infrastructure.”

⁸ See <https://insideclimatenews.org/news/22042022/valley-fever-climate-change>.

34	P25/L15-16	Here and elsewhere, acknowledge that heavy rains are projected to become even more heavy under climate change.
35	P25/L24	If possible, provide a number that this fraction amounts to, or at least a number for the total impact, so that the reader knows whether the small fraction is a large or small amount in absolute terms.
36	P26/L14	Does the forestry industry belong in this list of vulnerable industries?
37	P26/L14	It would be worth including the forestry industry itself in this list.
38	P27/L5	Bark beetles should be mentioned.
39	P27/L15	California-important work is worth citing here (e.g., Westerling, 2018).
40	P27/L27	This is as close as this chapter comes to acknowledging the climate-driven issue of bark beetles and the disturbances and wildfire risks they cause.
41	P28/L10	See Xu et al. (2022), which demonstrates 20 percent reductions of surface-air warming trends on and around managed forests and lands.
42	P28/L26	First mention of fire weather. This is a key instigator of wildfire in the Southwest. The question of whether instances of dire fire weather will increase with climate change is as important as the long-term secular changes in general dryness, etc.
43	P28/L30	The introduction of Indigenous ways of managing fire is a major topic around the Southwest. This late introduction of the topic is unfortunate. It should be discussed earlier and more.
44	P28/L30	In context of Key Message 28.4, at least, the lack of any mention of wildfire impacts on infirm and limited mobility persons, and remote underserved, under connected, and easily isolated communities is a problem (see, e.g., Blunt et al., 2022, California Burning; or Gee and Anguiano, 2021, Fire in Paradise, for examples).
45	P29/L27	For a study that documents this for the entire Southwest, and indeed the continental United States, see Albano et al. (2022).
46	P30/L6	The temporal variability of recharge rates and locations is even less well understood. It is also more directly tied to understanding and quantifying the likely impacts of climate change on recharge.
47	P30/L11	Add atmospheric rivers to this list of precipitation mechanisms/modes that need more climate-change research.
48	P30/L19	This reliance on intuition is problematic here. At the very least, history tells us that Indigenous and rural people and communities are often better “equipped” with traditional ecological knowledge to not locate themselves where risks are high.
49	P31/L2-3	Provide a citation for this statement. There are dozens of studies that have shown that snow-fed streamflow (runoff) amounts have not been declining, in contrast to snowmelt timing, among others. If this statement is intended to mean that the part of runoff that comes from the declining snowpacks is declining, this may be true; but runoff in (historically) snow-fed streams of the Southwest has not been shown

		to be declining (e.g., Barnett et al., 2008). If the former is what this is intended to say, please reword to be clearer.
50	P35/L34	West Nile virus is not discussed in the body of this chapter and does not belong in this traceable account.
51	P37/L7	It is odd that, after not referencing Westerling’s seminal work at all in the body of this chapter, his work appears front and center in this traceable account. The traceable account should not introduce new citations.

CHAPTER 29: ALASKA

#	Page/Line	Comment
1	P3/L4-6	Suggest adding references for, “glaciers are shrinking, permafrost is thawing, and sea ice is diminishing. The growing season is longer, and fish, birds, wildlife, and insects have increased in numbers in some areas and dropped sharply in others.”
2	P3/Figure 29.1	Title in text does not match title embedded in figure. Add scale and legend. Great caption. This could be an example for other figures that synthesize a large amount of information.
3	P4/L11	“...a wide variety of more recent arrivals” is unclear. Does this mean that recently non-Alaska Native Indigenous peoples have migrated to Alaska? If so, is that number represented in the one fifth population reference?
4	P4/L11	Suggest using more precise language than “recent arrivals.” For example, briefly discuss the periods of settlers arriving to the state.
5	P4/L14-16	Suggest adding references.
6	P4/L25-27	Suggest adding references.
7	P5/L4-9	What are the projections under other scenarios? Or justify why only RCP8.5 was used.
8	P5/L10	Suggest revising “Many of the most evident” to “More obvious impacts.”
9	P5/L10-14	Suggest adding references for each of these claims. The Committee notices that the ocean and climate related statements are much better referenced overall as compared to the cryosphere related references.
10	P5/L20-27	Projections of a wetter Alaska are treated as almost beneath notice, but it is likely that in a warmer Alaska, more precipitation is likely to cause even more transportation and ecosystem issues and accelerate the thawing of permafrost. Alaska is already seeing more intense and prolonged storms due to poleward migration of Pacific storm tracks and possibly increased meridional loops and flows associated with thawing of the Arctic Ocean.
11	P5/L28	Change “affect” to “will affect.” This paragraph is not strictly or even mostly about the climate changes thus far, and instead is mostly about projections.

12	P5/L31	Suggest changing “limit” to “constrain.”
13	P5/L33-34	Suggest adding references.
14	P6/Figure 29.2	The park road illustration doesn’t accurately capture the nature of the problem. Briefly describe why these two case studies were chosen for the figure. Page 29-6, line 4: Change tourist economy to tourism economy. The Ocean Conservancy is cited, but it would be better to cite the sources of data presented in the figure.
15	P7/L3-11	This discussion could be strengthened if it were expanded on some. Why is responding to climate change uniquely complicated in Alaska?
16	P7/L7-8	This is not the most illustrative example. An earthquake is a very different kind of event as compared to climate change. For example, there are good warning and coordination systems in place, and so “Alaskans working together” is true, but they are supported by extensive, established systems of response.
17	P8/Table 29.1	Suggest adding or editing to “nature-based solutions.”
18	P8/Table 29.1	This is a really nice table. The table could be improved by removing some jargon (i.e., ecosystem based) and also adding key message numbers.
19	P8/L6	Key Message 29.1. Our Health: Suggest adding likelihood evaluations. Consider an alternate word to resilience or expand on this—resilience to what?
20	P9/L1-3	Suggest adding references to support this statement and use more precise language than “many Alaskans”.
21	P9/L14-16	This could be strengthened with more references.
22	P10/L10-11	This statement: “adaptations have the potential to exacerbate these inequalities” could use some additional context. It reads somewhat abstract; perhaps offer an example?
23	P10/L23-24	Could chapter authors say something more specific about how rabies and climate are connected? For example, “...with potential connections to changing climate conditions, because of the shifting range of species [citation].”
24	P10/L32-39	Suggest chapter authors more explicitly connect the dots between harmful algal blooms (HABs) and food sources, to further discuss why HABs matter for human health. It is not explicit in this paragraph.
25	P11/L3-6	Was this because of indoor plumbing? How do other factors like co-habitation affect this relationship? If more than one factor is described in the study, it might be better to frame this as a contributing factor versus a causal relationship.
26	P11/L12	A figure allowing the reader to envision how the pass is structured and works here would be very effective.
27	P11/L19-20	“As an example illustrates” is odd wording. Is there supposed to be an example here that is missing?
28	P11/L21-22	Suggest adding a reference for the link between mold and pregnancy.

29	P11/L28-36	The Committee agrees with the points raised on mental health impacts due to climate change. However, the citations are on First Peoples located in Canada. We suggest referencing research conducted with Alaska Natives or generalize the statements. If citations are not available, then suggest changing “Alaska Native populations whose ... are particularly vulnerable” (line 33) to “are potentially vulnerable.”
30	P12/L1-11	This paragraph addresses COVID-19 essentially from the perspective of “is the health care system up to ‘it’ for COVID and other disasters.” But in Alaska, the problem of getting people to the health care system is often the real crux. Some discussion of how transportation improvements play into the effectiveness of the health care system would be very helpful here.
31	P15/Figure 29.5	Very nice figure. The Committee suggests adding a summary in the caption as to why the proportion of race by region matters.
32	P16/L16	Whose data are these from fall 2018?
33	P18/L3-4	Consider adding to each of these claims (climate change contributing to collapse and collapse undermining jobs/ways of life).
34	P19/Figure 29.7	Significant parts of Alaska’s “modern” economics and services base have been built upon, and rely upon, the fossil fuel industry. As much as any place in the country, when mitigation requires major changes and cutbacks of that industry, what will be the impacts on Alaska’s communities?
35	P20/L5	How many fishery disasters has Alaska had? Since 14 are listed perhaps add total number of disasters (e.g., 14 of X) or omit the number entirely.
36	P20/L11-12	Consider adding references here for how climate change is impacting each species listed.
37	P21/L5-10	Suggest adding references.
38	P22/Figure 29.8	Perhaps the authors can find another image to better convey their point of importing fish into a fishing community.
39	P22/L5	Key Message 29.4. Our Built Environment: Suggest rephrasing part of the key message to consistently format the likelihood statements (i.e., “Further warming will to lead to greater needs and costs for maintenance or replacement of buildings, roads, airports, and other facilities (<i>high confidence, very likely</i>)).
40	P23/L22-23	Might consider adding something about how there have been efforts to broadly model permafrost, but localized assessments are not available, and cite associated modeling efforts.
41	P24/L5	Consider using a different term than managed retreat because of its problematic connotations.
42	P24/L10-18	Authors might consider briefly mentioning the legal challenge related to relocation, in that no one entity seems to be legally responsible to pay for these moves.

43	P24/L27	This paragraph discusses climate impacts on the fossil fuel industry but should discuss the impact of (likely) major changes in that industry, in reaction to climate change, on Alaska.
44	P25/L14-18	This could be strengthened by adding references to support the discussion about conflicts over fish and wildlife resources.
45	P29/L11-14	This section could be strengthened with a good definition of security. The differing kinds of security explained feel like they were forced together, but a good definition could help make this section more coherent.
46	P30/Figure 29.13	Suggest splitting this figure into two because the text and information is nearly too small to read.
47	P30/L16-21	This section could be strengthened with more references.
48	P30/L22	The Committee is unclear as to whether this paragraph is mostly talking about opening of the Bering Sea, versus more about opening of the Arctic Ocean traffic.
49	P31/L25	This word likely should not be italicized, because it is not within a key message.
50	P32/Box 29.7	Nice balance of local perspective and the broader context needed to understand the comment. This could be a reference for the other boxes.
51	P32/L12	Change “would” to “will.”
52	P39/L29	Consider adding climate impacts on other racial/ethnic groups in Alaska to the research gaps section.

CHAPTER 30: HAWAI‘I AND US-AFFILIATED PACIFIC ISLANDS

#	Page/Line	Comment
1	P10/L14	How does rising temperature affect freshwater resources? Is there a reference that directly relates temperature to freshwater resources? The other factors listed are clearly relevant, but temperature should be removed from the list if no reference exists to provide a verifiable physical link.
2	P10/L24	Most traditional fishponds (at least in Hawai‘i) are saltwater or brackish. This section is about freshwater resources, so please clarify that this refers to traditional freshwater fishponds or remove if not.
3	P10/L25	Same as above for energy and microgrids. Are these related to freshwater resources?
4	P11/L14-15	This should be added to research gaps on page 30-36.
5	P12/L4-5	Is there information about such declines for the Pacific Islands in particular?
6	P12/L16	Is the semicolon supposed to be after the Galappaththi reference?
7	P12/L17	Should this be “and <i>decrease</i> local access?”
8	P13/L16-19	This sentence was challenging to digest quickly. Suggest replacing “flooding depressing” with “increased flood frequency depressing.”

		Also suggest replacing the semicolon with a period. The sentence about Hawai‘i is a separate statement.
9	P14/L20	Suggest replacing “length, this increases” with “length, the project increased.”
10	P16/L9-13	The citations provided here pertain to the increases in the physical climate events, but the way this sentence is phrased, it could be read as if these references connect the physical events to health (which they do not). To avoid confusion and misattribution, it would be best to restructure this sentence to lead with stating the that the physical events will increase with the stated references, and then follow with the statement that the events will be connected to increasing health impacts and add references (perhaps referring to those in the following paragraph).
11	P18/L17-26	This paragraph only mentions climate in passing. Suggest reworking to provide more concrete connections to climate (rather than general epidemiological trends), perhaps via the references on line 20?
12	P21/L11	Period missing at the end of the paragraph.
13	P32/L33-34	A word is missing in this sentence between “protecting” and “from.”
14	P40/L11-14	This is pertinent information that should be repeated for any key messages that use these models (or similar) as a basis.

CHAPTER 31: ADAPTATION

#	Page/Line	Comment
1	P3/L5-7	Refer to Chapters 2 (Climate Trends) and 3 (Earth System Processes) rather than literature.
2	P3/L9-14	It seems this point on whether incremental adaptation is sufficient, which is critical to the chapter, should not be in the introduction, but addressed in more depth in the key messages. The first sentence is quite vague. Hard for the reader to know where the statement applies.
3	P3/L13	Suggest including “regions” with levels and sectors.
4	P3/L28-30	This is policy prescriptive. Could say “Shi and Moser find....”
5	P7/L9-11	This sentence is unclear as written. Fossil fuel reliant communities cannot adapt?
6	P7/L32-34	This is a very important sentence given the emphasis of the chapter on the need for transformative adaptation. Is the failure of incremental adaptation expected under all climate change scenarios, for example, even those limiting warming to 2 or 1.5°C?
7	P8/L5-7	Does the statement about insufficiency of funding for adaptation consider the funding for adaptation in the Bipartisan Infrastructure Bill and the Inflation Reduction Act, both enacted in 2022?
8	P9/L5	Suggest key message title be more of a statement and less of a label.
9	P13/L1	Suggest key message title be more of a statement and less of a label.
10	P13/L24	Suggest adding wildfire to this list.

11	P14/L15	Suggest changing out “amenities” for something more detailed like “economic development” or “workforce.”
12	P14/L15	Are matching funds also a barrier?
13	P14/L32	Does this fire reference refer to urban fires or wildfires?
14	P16/L5	Suggest either including communities after “wealthy” or rewording the sentence to be clearer. Adaptation for well-resourced communities may lead to negative outcomes for already overburdened communities.
15	P16/L26	Suggest key message title be more of a statement and less of a label.
16	P18/L3	Please add states to “some cities and utilities,” as some states also have centralized offices focused on resilience and/or sustainability.
17	P18/L14	Suggest adding the chapter title with the reference.
18	P18/L18-25	The paragraph is policy prescriptive but can be rewritten.
19	P19/L23	The paragraph is policy prescriptive.
20	P20/L21	Suggest key message title be more of a statement and less of a label.
21	P24/L9	Suggest key message title be more of a statement and less of a label. Suggest more approachable language like “Paying for Adaptation.”
22	P24/L11	Recommend ordering the key message statements with medium confidence statements last, not first.
23	P25/L30	Remove “but.”
24	P26/L1	Figure 31.6 may not communicate what the authors are trying to communicate. Rethink if this should be showing that there is no financial incentive to proactively adapting coastal properties and if proactive adaption costs are missing from rail or so faint they cannot be seen. It also appears that no additional costs are similar to reactive adaptation costs.
25	P27/L22	Suggest adding titles to the key messages being referenced here and throughout.
26	P27/L23	Suggest adding titles to the key messages being referenced here and throughout.
27	P28/L34	Suggest adding titles to the key messages being referenced here and throughout.

CHAPTER 32: MITIGATION

#	Page/Line	Comment
1	P3/L2-4	This sentence is a confusing sentence to start out the chapter with. Also, the introduction is short. Suggest starting with a summary or definition statement about mitigation (like the second sentence, line 5) and then providing an overview of the chapter before delving into key messages.
2	P3/L19	Suggest in-line definition of the Paris Agreement and description of nationally determined contributions (line 25) for general audiences.

3	P3/L22-24	Please add to the sentence that net-zero can be reached earlier than mid-century depending on considerations of international equity and burden-sharing (van Soest et al., 2021). Reaching net zero before mid-century would also likely be a lower cost scenario (Schaeffer et al., 2020).
4	P3/L28	If the number is negative 6 percent or a decline, suggest spelling out negative or stating that this is a decline.
5	P4/L1	In the figure, the net-zero label on the graph is a bit confusing because the graph shows just emissions, not emissions and sinks. Suggest relabeling the graph to highlight the years when emissions reductions goals will occur rather than the “net zero emissions benchmarks.”
6	P4/L15-16	Suggest defining key GHG “sources” and “sinks” in this section, and then describing major trends among those. Suggest adding projections 50 and 100 years into the future to meet statutory charge. In this first section, suggest including citations for where all the data are from.
7	P4/L18	Is there a reason the net emissions are depicted with the end year of 2019 rather than 2020 or 2021? Perhaps pandemic-related anomalies? Suggest explaining this in the traceable accounts section.
8	P5/L5-6	Suggest a citation after this sentence.
9	P5/L9-11	This sentence is not clearly written. Suggest more clearly specifying what is offsetting what and suggest defining emissions intensity and energy intensity in-line, for audiences: “changes in US energy-related emissions were primarily driven by increases in population and GDP per capita. However, these increases were offset by decreases in energy related GHG emissions, emissions intensity, and energy intensity. Energy intensity refers to ___, while emissions intensity refers to ____.” Does “Decreases in energy emissions” refer to energy intensity? If yes, then please use “energy intensity” so the supporting text aligns with the labels in the figure.
10	P6/L1-6	Suggest describing the relationship between the energy sector and the electricity sector (e.g., electricity sector emissions comprise what portion of energy sector emissions).
11	P6/L1-6	Suggest explaining why coal use declined and renewables increased (e.g., tax credits, gas prices).
12	P6/L7-12	Spell out “MWh” and ensure broad audiences can understand the figure.
13	P6/L14-20	Suggest noting what forms of transportation use the fuels listed and are the highest emitters (e.g., cars, trains, planes). Be specific so audiences can understand linkages to their lives.
14	P6/L19-20	Suggest defining what “vehicle-km” is for the audiences. Suggest clarifying text: “improvements in energy per vehicle-km were more modest” (and suggest what a negative 8.6% means). Also, consider including a time range for when the change the sentence discusses occurred.

15	P11/L4	This is a great example of an in-line definition and provides a great reference for how to do this where the Committee has suggested adding in-line definitions in other places.
16	P11/L17-27	May want to consider defining “dispatchable or firm” for audiences.
17	P11/L29-31	Great job including recent developments (i.e., IRA), though the IRA is likely to help all electricity sources not just solar and wind.
18	P11/L35-36	The phrase “assuming appropriate market structures and incentives” is unclear. Please add more language to clarify what this clause actually means.
19	P12/L10-13	Consider adding a sentence discussing the ability to expand transmission and interregional infrastructure.
20	P13/L1-2	Figure 32.9(b) is not clear in what it is depicting, and the caption is not helpful to describe it. Suggest adding labels to the figure on the y-axis and indicating the timescale on the graph.
21	P14/L3	List examples of alternative fuels (i.e., “such as ...”).
22	P15/L7-13	This sentence is hard to follow, particularly the last two clauses: “fundamental changes in processes as well as carbon capture and storage.” What are the fundamental changes in processes referred to? What are the challenges expected with CCUS? Suggest: “Similarly most industrial energy demand could be electrified using existing technologies. Achieving net-zero emissions in some industries may present special challenges—particularly related to the costs of supplying high-temperature heat with electricity, adapting to changes in processes, and developing regulatory frameworks to support carbon capture and storage projects.”
23	P16/L4	Offset “thus” with commas.
24	P16/L9	How is this food wasted? Individuals, in production, by commercial industry? Give examples if possible.
25	P16/L31-34	Not sure “tasty” fits well in this sentence.
26	P24/L9-15	This discussion is very similar to the discussion under Key Message 32.2 that discusses shifting diets. It could be mentioned there and removed from here to save space.
27	P28/L1-6	Figure 32.16 is not cited to in any of the supporting text.
28	P31/L28-33	This discussion might warrant mention of recent legislative actions attempting to address these disparities (e.g., IRA tax credits for electric vehicles, two-tier tax credit system now encouraging consideration of apprenticeships and community where sited).
29	P32/L1-5	This caption needs much more description.
30	P34/L1-4	Suggest caption include description of what classifies a “mitigation” activity. Many cities, universities, and local groups have acted in the absence of state leadership. Some states have governor leadership (i.e., executive orders) without legislative action, vice versa, or both.
31	P38/L1-6	Figure 32.22: The Committee recognizes that this figure is under development, but as presently depicted, it is unclear based on the multiple titles and labels on the figure whether the figure is depicting emissions reduction potential by abatement measure, savings per

abatement measure, cost per MMT of CO₂e offset by each abatement measure, incremental cost per MMT of CO₂e offset by each abatement measure, or some combination because the language and labels indicate all of the above. The Committee suggests adding much clearer labels, titles, and very clear caption text to explain this figure in both this chapter and Chapter 1 (Overview) (Figure 1.18). The x-axis should be labeled in the correct units and the box should be labeled in the correct units with the color gradients much more distinct (blues and yellows are not distinguishable from each other). In the caption, the term “marginal costs” should be explained as well as the key takeaways from the figure. Please give an example for the audiences from/using the figure.

FOCUS FEATURE ON COVID-19 AND CLIMATE CHANGE

#	Page/Line	Comment
1	P F3-2/L8	Please add Mora et al. (2022) to the references.

APPENDIX 3

#	Page/Line	Comment
1	P A3-3/L1-7	Figure should be self-standing so more information about each panel needs to be presented.

APPENDIX 4

#	Page/Line	Comment
1	P A4-8/L3-22	The discussion on billion-dollar disasters needs to note the complexity of this indicator and how it is not just influenced by change in frequency and intensity of extreme events but also by exposure to such events. The Committee’s comments on the billion-dollar damages figures in Chapter 1 (Overview) and in Chapter 2 (Climate Trends) point out that the increase in the number of billion-dollar disasters may also be the result of increased population, particularly in hazardous areas, and in property values rising faster than the Consumer Price Index. Indeed, this indicator provides an excellent opportunity to discuss the complexity of some indicators, particularly those that measure societal impacts. The discussion should point out that such impacts can be affected by many factors.

Appendix B

Committee Member Biographical Sketches

Joel B. Smith (*Chair*) is an independent researcher and member of the National Academies' Advisory Committee to the US Global Change Research Program (USGCRP). Mr. Smith has provided technical advice, guidance, and training on assessing climate change impacts and adaptation to international organizations, the US government, states, municipalities, and the nonprofit and private sectors. He was a member of the National Academy of Sciences' Panel on Adapting to the Impacts of Climate Change. He was a coordinating lead author or lead author on the Third, Fourth, and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change. Mr. Smith was also an author of three US National Climate Assessments (NCAs), including Chapter Lead on the International Chapter for the fourth NCA. He has been a consultant since 1992, having worked for Hagler Bailly, Stratus Consulting, and Abt Associates. He worked for the US Environmental Protection Agency (EPA) from 1984 to 1992, where he was the deputy director of the Climate Change Division. Mr. Smith received a BA from Williams College in 1979 (graduating magna cum laude), and an MPP from the University of Michigan in 1982. Mr. Smith served as a Special Government Employee with EPA from May 2021 through February 2022; he did not work on matters directly relevant to USGCRP. Over the past 5 years, Mr. Smith co-authored a peer-reviewed paper with Marcus Sarofim (co-author on NCA5 Chapter 19 [Economics]), who at the time was a client at EPA while Mr. Smith worked at Abt Associates, and he serves as a member of the Advisory Committee to the USGCRP with Kris Ebi (co-author on NCA5 Chapter 15 [Human Health]).

Marissa Aho, AICP, has served as the Policy Director/Chief Resilience Officer for the Washington State Department of Natural Resources since July 2021. She previously served as the first Chief Resilience Officer for the cities of Los Angeles and Houston. She led the development and implementation of the cities' resilience strategies (Resilient Los Angeles and Resilient Houston) that are focused on preparing for catastrophic events and addressing chronic stressors. She is a member of the American Institute of Certified Planners. She has a BA in political science and communications, legal institutions, economics, and government from American University and a Master of Planning from the University of Southern California. Ms. Aho has worked with multiple NCA5 contributors in different capacities over the past 5 years: she served on the Resilient Los Angeles working group with Juliette Finzi Hart (co-author of NCA5 Chapter 9 [Coastal Effects]) and Emmanuel Crisanto Liban (lead author on NCA5 Chapter 13 [Transportation]), she was the project lead on a Climate Assessment for Houston that Katharine Hayhoe (co-author of NCA5 Chapter 2 [Climate Trends]) was hired to conduct, she worked with Laura Patino (contributor of NCA5 Chapter 26 [Southern Great Plains]) on Resilient Houston, she also worked with Earthea Nance (co-author for NCA5 Chapter 18 [Sector Interactions, Multiple Stressors, and Complex Systems]) on multiple projects in Houston, and she served as a Chief Resilience Officer with Daniel Zarrilli (co-author of NCA5 Chapter 21 [Northeast]) and both contributed to 100 Resilient Cities work.

Shanondora Billiot (United Houma Nation) is an assistant professor at Arizona State University. Her research uses mixed methods to understand Indigenous-specific risk and

protective factors to global environmental change exposure and pathways to health outcomes within Indigenous populations with the goal to co-develop adaptation activities. Dr. Billiot is currently a co-principal investigator on an interdisciplinary team exploring resilience, culture, climate, and movement among an Indigenous community on the Gulf Coast funded by a Gulf Research Program Thriving Communities Grant. She serves as a Technical Advisory Member of the Climate Change Taskforce for the National Congress of American Indians and is a member of the Community Board for Engagement and Evaluation of the Gulf Research Program within the National Academies of Sciences, Medicine, and Engineering. She earned a PhD in social work from Washington University in St. Louis as a Henry Roe Cloud visiting doctoral fellow at Yale University.

Michael Dettinger (NAE) is a visiting researcher at the Center for Western Weather and Water Extremes at the Scripps Institution of Oceanography and a part-time researcher at the Desert Research Institute. He retired from the US Geological Survey (USGS) as a senior research hydrologist in 2019 after 38 years studying climate and water resources in the western United States. Dr. Dettinger continues his research on hydroclimatic variability, extremes (including atmospheric rivers and droughts), and climate change impacts and adaptations. He is a fellow of the American Geophysical Union (AGU) and the American Association for the Advancement of Science, a member of the National Academy of Engineering, and is a recipient of two California Climate Science Service Awards. He has authored more than 150 scientific articles in scholarly journals and books, more than 30 government reports, and 100 articles and reports in other outlets. These publications have been cited more than 32,000 times in the scientific literature, with more than 70 cited 100 or more times each. He was a lead author of the 2013 Third National Climate Assessment Water Resources chapter, co-edited State of Bay-Delta Science Reports in 2008 and 2016, led the California Fourth Climate-Change Assessment Sierra Nevada Region Report in 2018, and was the AGU Tyndall Lecturer on History of Global Environmental Change in 2021. He earned his MS in civil engineering at the Massachusetts Institute of Technology and his PhD in atmospheric sciences at the University of California, Los Angeles, in 1997. In the past 5 years, Dr. Dettinger has published on California's Fourth Climate Change Assessment report, California drought, climate change scenarios, and extreme precipitation. He has also given technical and public talks in recent years on local-to-regional climate change science. Dr. Dettinger has collaborated with three NCA5 contributors over the past 5 years: he has co-authored a publication and collaborated on a workshop panel with Paul Ullrich (co-author on NCA5 Chapter 3 [Earth System Processes]), collaborated on a Nevada State Climate-Change Vulnerability Assessment with Stephanie McAfee (co-authored NCA5 Chapter 4 [Water]), and he served as a principal investigator on a USGS-funded Southwest Climate Adaptation Science Center with Erica Fleischman (co-author on NCA5 Chapter 27 [Northwest]).

Janet Franklin (NAS) is the Endowed Campanile Foundation Department of Geography at San Diego State University. She is a Distinguished Professor of Biogeography Emerita, retired from the University of California, Riverside. Her work addresses the impacts of human-caused landscape change on the environment. Her research has garnered new insights into the impact of fire regimes on ecosystems and the role of early humans in shaping ecological communities. In 2014, Dr. Franklin was elected to the National Academy of Sciences (NAS) for her significant advancement of the understanding of human impacts on ecosystems by developing novel species distribution models, combined with innovative geospatial analysis and extensive fieldwork. She

is currently a member of the NAS Geographical and Geospatial Sciences Committee and served as the co-chair of the joint NAS-Royal Society Forum on Climate Change & Ecosystems (2018). She received her PhD and MA in geography and a BA in environmental biology from the University of California, Santa Barbara. Dr. Franklin co-published an editorial introduction to “Climate Change and Ecosystems—Threats, Opportunities, and Solutions” in the *Philosophical Transactions of the Royal Society B*. Dr. Franklin has co-authored publications over the past 5 years with Forrest M. Hoffman (co-author on NCA5 Chapter 3 [Earth System Processes]) and David Hondula (co-author on NCA5 Chapter 12 [Built Environment, Urban Systems, and Cities]).

Jada Garofalo is an associate in the Domestic Environment and Natural Resources Division at Abt Associates. Her expertise intersects multiple topic areas, including climate impacts, adaptation, and mitigation; environmental regulations; water law, regulation, and policy; energy and energy-transition regulation and policy; health, including nutrition, and infectious and vector-borne diseases; and social and environmental justice issues. Ms. Garofalo blends her science and legal skills to develop purposeful research and policy in the climate arena. Currently, she is engaged in interdisciplinary project leadership, management, and development on issues related to climate impacts and adaptation to the energy, environment, health, and water sectors, and climate mitigation. Ms. Garofalo earned her BS in food science and human nutrition in 2010, followed by her MS in climate science and policy in 2014, and her JD in environmental law in 2019. As an attorney, Ms. Garofalo has represented clients on siting of wind development projects and has served as a panelist for webinars on legal considerations for advanced and renewable energy and clean energy standards. Ms. Garofalo has recent publications on rare earth elements, carbon capture, and CO₂ pipelines. Ms. Garofalo conducts work under a contract for the US Army Corps of Engineers with Ariane Pinson (federal coordinating lead author on NCA5 Chapter 4 [Water]).

Shineng Hu is an assistant professor in the Division of Earth and Climate Sciences, Nicholas School of the Environment, Duke University. Dr. Hu specializes in climate dynamics and air–sea interactions. The main goal of his research is to understand the ocean’s role in global climate variability and change through the interaction with the atmosphere. Dr. Hu received the National Aeronautics and Space Administration’s Earth and Space Sciences Fellowship in 2014–2017, the Scripps Institutional Postdoctoral Fellowship and the Lamont-Doherty Postdoctoral Fellowship in 2018. Dr. Hu obtained his BS in atmospheric science from Peking University in 2012, and his PhD in climate dynamics from Yale University in 2018.

Richard Jackson (NAM) is professor emeritus at the University of California, Los Angeles, Fielding School of Public Health, where he was the department chair in environmental health sciences. A pediatrician, he has served in many leadership positions with the California Health Department, including the highest as the State Health Officer. He served as the director of the Centers for Disease Control and Prevention’s National Center for Environmental Health for 9 years and received the Presidential Distinguished Service Award. He was elected to the National Academy of Medicine (NAM) in October 2011, where he was the co-leader of its Climate Interest Group and in October 2022, he received NAM’s David Rall medal for service. Dr. Jackson was instrumental in establishing the California Birth Defects Monitoring Program and instigating state and national laws to reduce risks from pesticides, especially to farm workers and

to children. He has received the John Heinz Award for national leadership in the Environment; the Sedgwick Memorial Medal, the highest award of the American Public Health Association; and the Henry Hope Reed Award for his contributions to architecture. Dr. Jackson co-authored the books *Urban Sprawl and Public Health*, *Making Healthy Places*, and *Designing Healthy Communities*. Dr. Jackson earned an MPH in epidemiology from the University of California, Berkeley, and an MD from the University of California, San Francisco, School of Medicine.

Rachael Jonassen is the director of Climate Change and Greenhouse Gas Management programs in the Environmental and Energy Management Institute as well as an associate research professor of urban sustainability at The George Washington University. Her primary appointment is in the Department of Engineering Management and Systems Engineering. She served as the senior climate scientist at the Logistics Management Institute advising the Obama administration and New York City on greenhouse gas management and climate impacts after 4 years at the National Science Foundation (NSF), directed carbon cycle science and biogeoscience research and represented NSF at the United States Global Change Research Program, leading on international efforts on carbon cycle research and managing the North American Carbon Program. Prior she was a professor of hydroclimatology where she developed and applied downscaling methods for climate change assessments for hydroelectric systems and biogeographic problems and supported the US Department of Energy on high-level nuclear waste efforts. She was recognized for her service at NSF with the Director's Award and is a fellow of the Geological Society of America. She serves on the National Cooperative Highway Research Program panel 15-61. Dr. Jonassen holds a PhD and an MS from The Pennsylvania State University and a BA from Dickinson College. Dr. Jonassen advises international climate change mitigation and adaptation with the Asian Development Bank, the World Bank, and the United Nations. Through the Center for Climate and Security, she is a signatory of "A Climate Security Plan for America."

Natalie Mahowald is the Irving Porter Church Professor of Engineering at Cornell University in the Department of Earth and Atmospheric Sciences. Before joining Cornell in 2007, she completed her postdoctoral work at Stockholm University, was an assistant professor at the University of California, Santa Barbara (1998-2002); and was a Scientist (I, II, and III) at the National Center for Atmospheric Research (2002-2007). The focus of Dr. Mahowald's work is on natural feedbacks in the climate system, how they responded in the past to natural climate forcings, and how they are likely to respond in the future. This includes building new parameterizations within Earth system models that couple new areas: for example, aerosols and biogeochemistry, or fires within the Earth system, or the impacts of land-use on aerosols and the carbon cycle. Dr. Mahowald has received several awards and recognitions throughout her career, including the American Meteorological Society Henry G. Houghton Award, American Meteorological Society Fellow, American Geophysical Union Fellow, American Association for the Advancement of Science Fellow, and Guggenheim Foundation Fellow. She served as the lead author on two Intergovernmental Panel on Climate Change (IPCC) reports: Assessment Report 5, Working Group I and the Special Report on 1.5°C (SR1.5). She earned her MS in natural resource policy at the University of Michigan and her PhD in meteorology at the Massachusetts Institute of Technology in 1996. Dr. Mahowald has made public statements on SR1.5 of the IPCC and testified on the same topic to the House Committee on Science, Technology, and Space.

Regan F. Patterson is a newly appointed assistant professor of civil and environmental engineering at the University of California, Los Angeles (UCLA). Her research focuses on the intersection of air quality engineering, sustainable transportation, and environmental justice. She was previously the Transportation Equity Research Fellow for the Congressional Black Caucus Foundation (CBCF), where she conducted intersectional transportation policy analysis and research. Prior to joining the CBCF, Dr. Patterson was a postdoctoral research fellow at the University of Michigan Institute for Social Research, where she examined the linkages between air pollution and racial residential segregation. Dr. Patterson was a recipient of the US Environmental Protection Agency's Science to Achieve Results Fellowship, Switzer Environmental Fellowship, and the University of California (UC), Berkeley, Chancellor's Fellowship. Her dissertation research modeled the air quality and environmental justice benefits of state and local transportation policies for mitigating exposure to traffic-related air pollution. She earned her PhD in environmental engineering at UC Berkeley. She holds a BS in chemical engineering from UCLA and an MS in environmental engineering from UC Berkeley.

Yueming (Lucy) Qiu is an associate professor in the School of Public Policy at the University of Maryland, College Park. Her research group focuses on using big data with quasi-experimental and experimental methods to answer empirical questions related to the interactions among consumer behaviors, energy technologies, and incentives. Her research projects have been funded by the National Science Foundation, the Sloan Foundation, the Electric Power Research Institute, the US Department of Defense, and the Water Research Foundation. Dr. Qiu received her PhD from Stanford University and BS from Tsinghua University.

Charles (Chuck) Rice is a University Distinguished Professor and holds the Vanier University Professorship at Kansas State University as a professor of soil microbiology in the Department of Agronomy. He teaches courses and conducts research on soil health and climate change impacts. Dr. Rice received the honorary title of National Associate of the National Academies of Sciences, Engineering, and Medicine. He was named the Hugh Hammond Bennett Awardee by the Soil and Water Conservation Society, which recognizes exceptional service and national and international accomplishments in the conservation of soil, water, and natural resources. Internationally, he served on the United Nations' Intergovernmental Panel on Climate Change to author a report on climate change in 2007 and 2014 and was among scientists recognized when that work won the Nobel Peace Prize in 2007. Dr. Rice is a fellow of the Soil Science Society of America, the American Society of Agronomy, and the American Association for the Advancement of Science. He has also served in numerous capacities with professional societies including the president of the Soil Science Society of America in 2011. Dr. Rice currently chairs the Board on Agriculture and Natural Resources at the National Academies. He earned his degrees from Northern Illinois University and the University of Kentucky.

Anjali Sauthoff is an environmental health scientist who works with the government, nonprofit organizations, academia, and businesses on climate change, public health, equity, data justice, and the use of geospatial technology for scientific communication. She leads the Westchester County Climate Crisis Task Force Health and Community Resilience teams, develops university capstone projects, and works with communities to address equitable climate mitigation and adaptation. Dr. Sauthoff's prior academic research centered on the development of models to estimate exposure to air pollution and on strategies to decrease greenhouse gas emissions from

the transportation sector. She received her master's degree in neurobiology and behavior from SUNY Stony Brook and her PhD in environmental health science from Columbia University. Dr. Sauthoff currently serves on the New York State Climate Impact Assessment Health and Safety technical working group. She recently published a book chapter titled "Social Determinants of Health as a Framework for Addressing Urban Climate Adaptation" (D. Mutnick, C. Griffiths, eds., *The City Is an Ecosystem: Sustainable Education, Policy, and Practice*, London: Routledge), which focused on urban climate adaptation and justice.

David L. Skole is a professor of forestry and the director of the Global Observatory for Ecosystem Services in the Department of Forestry at Michigan State University. Prior to that he was a research professor at the Institute for the Study of Earth Oceans and Space at the University of New Hampshire. Dr. Skole is an advisor to the Forest Investment Program (World Bank Group) and led the development of its monitoring and reporting toolkit. His research focuses on the role of forestry and agriculture in global climate change, the use of geographical information for sustainable development and natural resource management, new methods and applications of Earth observations for global environmental change analytics, and mitigation and adaptation. He is the chair of the United Nations Program on Global Observations of Forest Cover; the National Science Foundation Advisory Committee on Environmental Research and Education; and the International Geosphere Biosphere Programme's Core Project on Land Use and Cover Change. He has been a member of several committees of the National Academies, including the Committee on Earth Science and Applications from Space. Dr. Skole earned a PhD in natural resources from the University of New Hampshire and a BA and an MS from Indiana University. He is now active in the emerging carbon financial markets and applications of his research to carbon sequestration and domestic and international climate change mitigation programs, and in developing methods for carbon offsets under cap-and-trade carbon regulations. This includes work with the California Climate and Forest Fund and the Chicago Climate Exchange, membership on US government advisory groups, and an advisory role for the Michigan Department of Natural Resources.

Philip R. Thompson is an associate professor in the Department of Oceanography at the University of Hawai'i at Manoa and the director of the University of Hawai'i Sea Level Center (UHSLC). As director of the UHSLC, he oversees the operation of an international network of sea-level monitoring stations—many distributed throughout the Pacific Islands—as well as the curation of widely cited sea-level datasets. He also serves as the principal investigator (PI) for research projects funded by the US Geological Survey, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration focused on understanding decadal climate variability, future tidal flooding, and the interaction of sea-level and waves in the nearshore environment. An emerging theme in his work is the co-production of research that facilitates science-based coastal management and tools that support effective science communication. Dr. Thompson earned a PhD in physical oceanography from the University of South Florida in 2012 and a BS in physics from North Carolina State University in 2004. Dr. Thompson has had professional ties with a number of contributors to NCA5 over the past 5 years: he has co-authored two papers with William Sweet (co-author of NCA5 Chapter 9 [Coastal Effects]), he has two current projects that are being funded by PI-CASC who is directed by Mari-Vaughn V. Johnson (federal coordinating lead author on NCA5 Chapter 30 [Hawai'i and US-Affiliated Pacific Islands]), he is a co-principal investigator on a current project with

Curt Storlazzi (co-author of NCA5 Chapter 30 [Hawai‘i and US-Affiliated Pacific Islands]), one of his current grants partially funds Christopher Shuler (co-author of NCA5 Chapter 30 [Hawai‘i and US-Affiliated Pacific Islands]), he is the direct supervisor of Matthew Widlansky (technical contributor of NCA5 Chapter 30 [Hawai‘i and US-Affiliated Pacific Islands]), and he has co-authored many papers with and has a current PI/co-PI relationship on three federally funded projects with Benjamin Hamlington (co-author of NCA5 Chapter 3 [Earth System Processes]).

Kristin Timm is a research associate at the Alaska Climate Adaptation Science Center at the International Arctic Research Center, University of Alaska Fairbanks. She previously worked and studied with the Center for Climate Change Communication at George Mason University and has spent more than a decade working as a science education project manager and professional science communicator. Dr. Timm’s expertise is in science and climate change communication, and the people and processes at the interface of science and society. Her dissertation investigated news coverage of the Fourth National Climate Assessment and the factors that influenced it. She has received several awards for her work, including the US Geological Survey Eugene M. Shoemaker Communication Award for effectiveness communicating complex scientific concepts. Dr. Timm has a PhD in communication from George Mason University and an MSc in interdisciplinary studies (science communication) and a BA in rural development: land, resources, and environmental management, both from the University of Alaska Fairbanks. Dr. Timm has collaborated with a number of contributors to NCA5 over the past 5 years: she has co-authored publications with Aparna Bamzai (co-author on NCA5 Chapter 25 [Northern Great Plains]), Shawn Carter (federal coordinating author on NCA5 Chapter 8 [Ecosystems, Ecosystem Services, and Biodiversity]), Jeremy Littell (co-author on NCA5 Chapter 29 [Alaska]), and Katharine Mach (chapter lead on NCA5 Chapter 18 [Sector Interactions, Multiple Stressors, and Complex Systems]). She co-authored publications and presently is co-chairing a journal special issue with Julian Reyes (co-author on NCA5 Chapter 27 [Northwest]) and Louie Rivers (co-author on NCA5 Chapter 22 [Southeast]), she has a proposal in preparation with Heidi Roop (co-author on NCA5 Chapter 24 [Midwest]), and she has co-authored publications and collaborated on proposals with Sarah Trainor (co-author on NCA5 Chapter 29 [Alaska]) and Kripa Akila Jagnnathan (co-author on NCA5 Chapter 18 [Sector Interactions, Multiple Stressors, and Complex Systems]).

Gary Yohe is the Huffington Foundation Professor of Economics and Environmental Studies (Emeritus) at Wesleyan University. He has published more than 150 scholarly articles on climate change and climate policy or economics germane to climate change of climate policy. He has published more than 70 opinion and communication pieces alone and with colleagues Richard Richels, Henry Jacoby, and Benjamin Santer in venues like *Scientific American*, *The Hill*, *The Guardian*, *Yale Climate Connections*, and the like. Springer Nature is publishing a collection of 35 of these essays later this year. As a very senior member of the Intergovernmental Panel on Climate Change, he shared the 2007 Nobel Peace Prize. He has served as the co-vice-chair of the Third US National Climate Assessment and on many National Academies’ panels—including Susan Solomon’s Stabilization Panel and both the Adaptation Panel and overarching panel of America’s Climate Choices. Dr. Yohe was educated at the University of Pennsylvania and received his PhD in economics from Yale University in 1975. Dr. Yohe has written an opinion piece article for *The Hill* titled “GOP-Controlled House: Children Playing Poorly in the Climate Change Sandbox” in November 2022.

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On Jun 22, 2025, at 6:42 AM, Steven Koonin <steven.koonin@gmail.com> wrote:

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Both are included in the integrated draft attached, which you are urged to read/comment/edit.

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Subject: Summary chapter

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In view of the substantial problems with NCA5 in failing to comply with the USGCRP mandate and the tenets of Gold Standard Science, along with the endemic bias in the climate community towards alarmism and policy advocacy on the issue of climate change, we do not see a clear path forward for the NCA6 at this time.

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SOMETHING ABOUT ENERGY POLICY???

<~WRD2957.jpg>
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Sent: Sunday, June 22, 2025 7:18 PM
To: Judith Curry
Cc: Ross McKittrick; Steven Koonin; Travis Fisher; Roy Spencer; Josh Loucks; Seth Cohen
Subject: Re: Summary chapter

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Both are included in the integrated draft attached, which you are urged to read/comment/edit.

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From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, June 21, 2025 10:32 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Cohen, Seth <seth.cohen@hq.doe.gov>
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SOMETHING ABOUT ENERGY POLICY???

<~WRD2957.jpg>

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From: Judith Curry <curry.judith@gmail.com>
Sent: Sunday, June 22, 2025 5:58 PM
To: Ross McKittrick
Cc: John Christy; Steven Koonin; Travis Fisher; Roy Spencer; Josh Loucks; Seth Cohen
Subject: Re: Summary chapter

I think this is now pretty good. But I think a clear message needs to be given that more than just a band aid is needed

I will try to do the natural variability chapter tomorrow

On Sun, Jun 22, 2025 at 12:10 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

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From: Ross McKittrick [ross.mckittrick@gmail.com]
Sent: 6/22/2025 7:10:08 PM
To: John Christy [climateman60@gmail.com]
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Attachments: 01.NCA5.Review.June20[JC][SEK][JCurry][RM].docx

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Review of the Fifth National Climate Assessment

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EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, Restoring Gold Standard Science. It enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

Good climate and energy policies should balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by operational demands and the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character, with greater uncertainties and hence need for expert judgement.

For those reasons, assessments of climate science that will be influential for policy making must include statements about the strength of knowledge. The IPCC's approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management (Aven 2017). Here are its elements:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

1.4 When Peer Review Fails

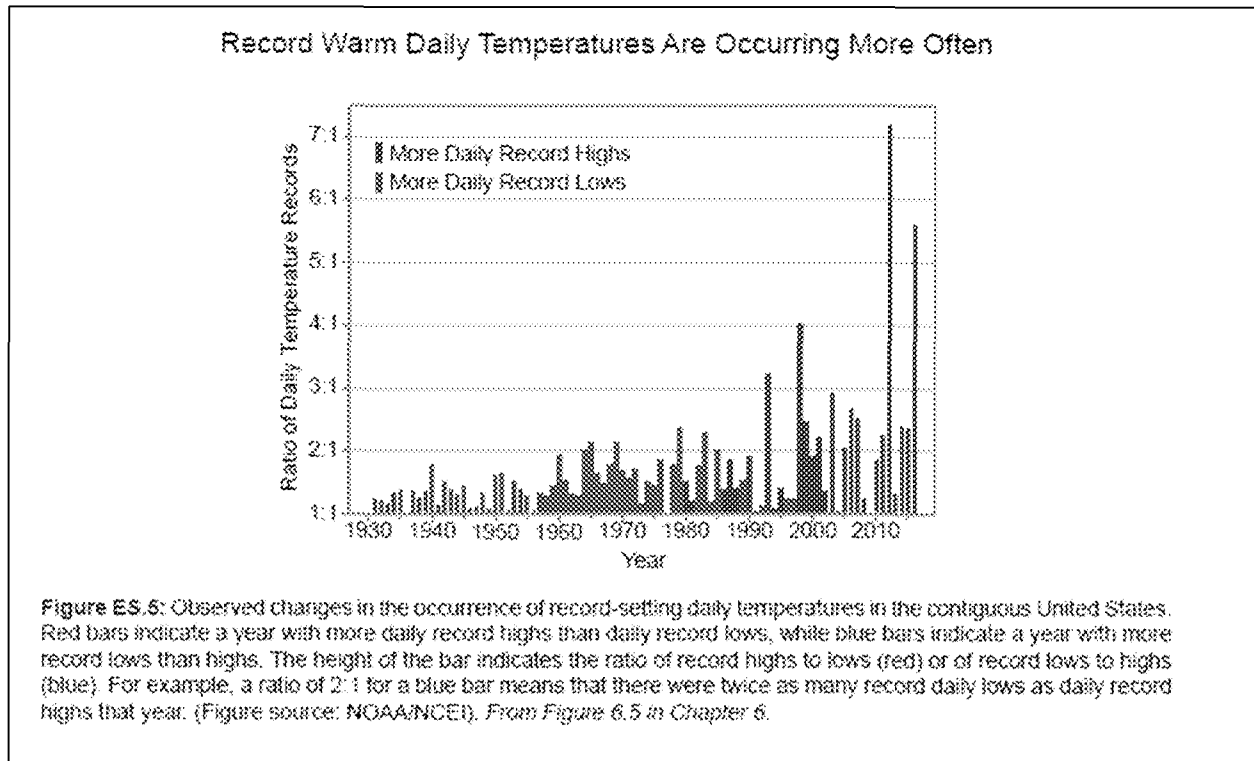
Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

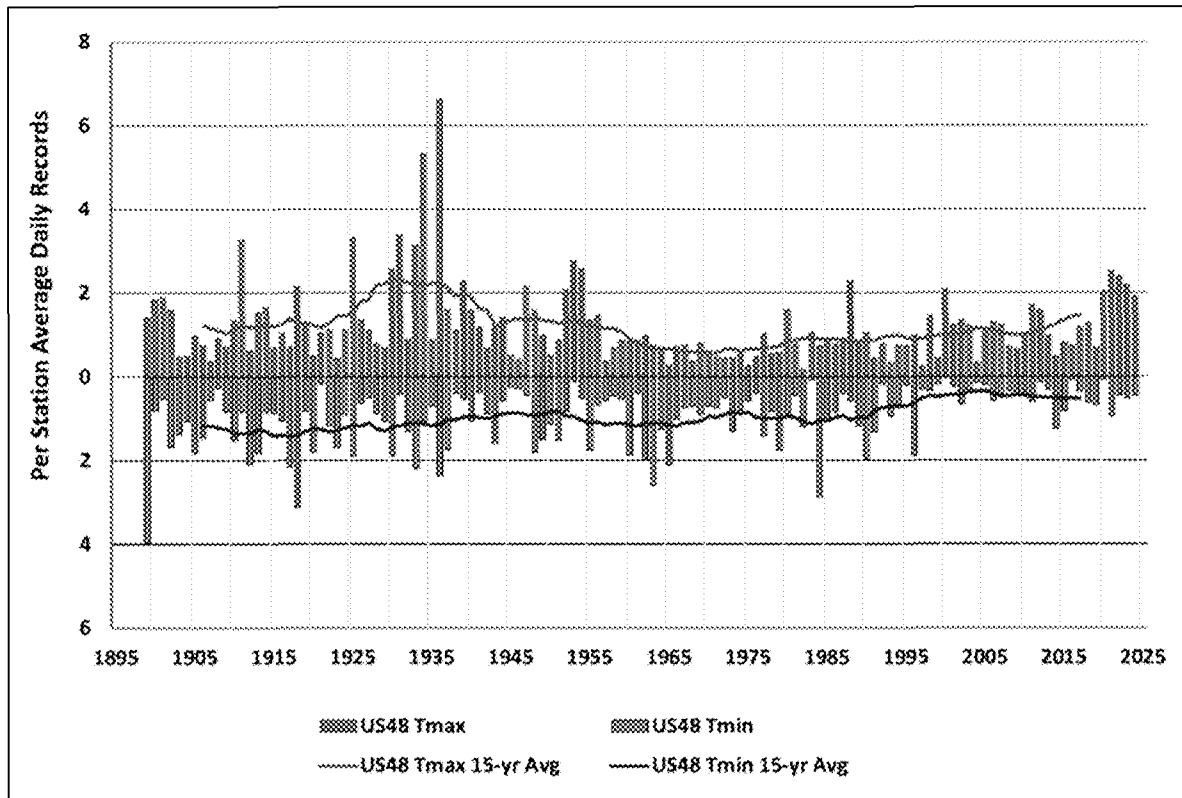


The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast,

25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel criticized the discussion of temperature extremes in a late draft of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) responded to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, “Overview”, holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with -- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5’s use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to “climate change”:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The change metric in NCA5 Figure 2.4 is non-standard; we will discuss NCA5’s inconsistent choices of time scales of analysis below. The claims were attributed to Knutson and Zeng (2018). But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 (Fig. 5) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories –3, –2,

+2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were anthropogenic. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly

influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models increased the uncertainty of ECS, rather than narrowing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

4 RELIANCE ON SHORT TIME PERIODS FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here are some examples of this problem from NCA5.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both

considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. We extended the data used in CWG25 (McKittrick and Christy 2025) to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). See details in Appendix 3. Many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find locations that support the NCA5 position, such as the Southeast post-1950, but results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions.

The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

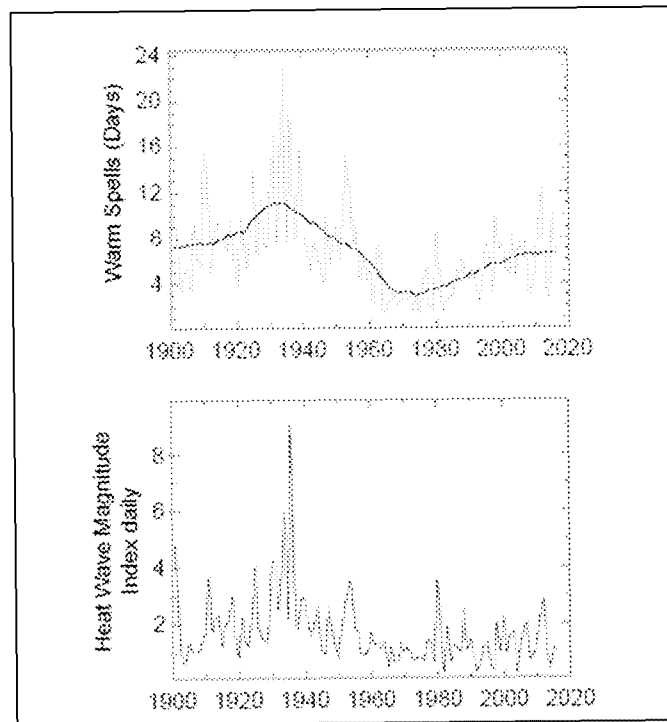
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

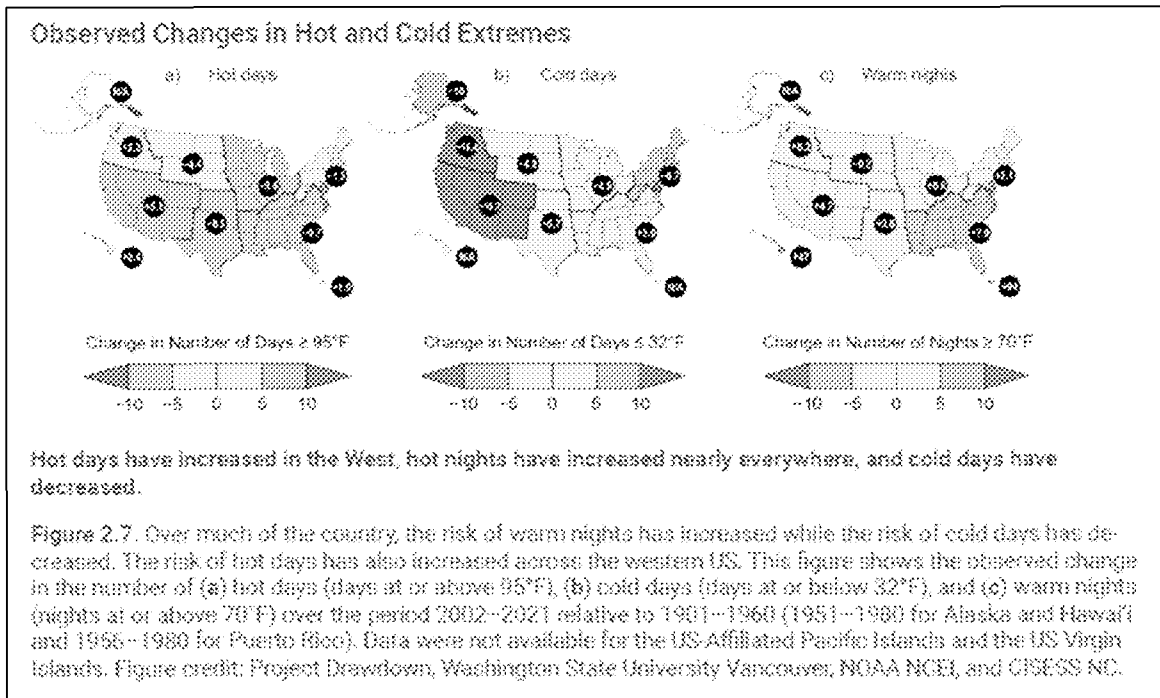
Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-

1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West NCA5 fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that

“multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the eyeball icon does not reveal the metadata information, instead a "Contact Us" email appears, addressed to the USGCRP. This is clearly an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.⁹						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

[I’ve made a start here – others need to weigh in]

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

NCA5’s use of the term “climate change” is ambiguous

As a result, NCA5’s attribution of various climate trends to “climate change” is misleadingly ambiguous. Consider its statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem, and it could have been easily addressed by adopting the phrase "changing climate" for general changes while reserving the term "climate change" for anthropogenic changes. But the NCA5 authors seemingly ignored their recommendation.

Here are some other examples where NCA5 had problems with natural variability ...

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, Chapter 2 did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed out (Section 4.2) that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title

of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5’s use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP’s charge: whether NCA5 (1) complied with the USGCRP’s statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refers to specific sections of this report as well as to the CWG25 Report.

8.1 Compliance with USGCRP’s statutory obligation

As cited in Section 1.2 of this Report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

We deem NCA5 to have fallen short when evaluated against these criteria. We have identified the following major shortcomings in NCA5 (each is detailed in the chapters cited):

- Inadequate assessment of the relevant topics in climate science and the hazard < [RM: I’m not sure what *hazard* is referring to. We haven’t defined the term or discussed it] components of climate impacts. NCA5 instead focuses on evaluation of societal vulnerabilities, “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Sections 3.1.5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter x NEW)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)

- Uncritical evaluation of emission scenarios and climate simulations in making projections for the next 25 to 100 years (Chapter 6; Chapter xx in CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the Chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review did not point them out and thus evidently lacked the rigor expected of Academies’ reports. (Section 1.4, NEW CHAPTER)

8.3 Suitability for informing Federal climate and energy policy

We assess that the selection and presentation of information in NCA5 makes it an unreliable basis for U.S. climate and energy policymaking. For each of the elements of knowledge characterization suitable for risk management listed in Section 1.3, here are specific examples where NCA5 falls short.

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios and made policy recommendations without adequate consideration of the costs
- The degree to which data/information exists and are reliable and relevant
 - NCA5’s assumptions about model reliability, and its use of short time periods for analysis does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, the concerns we have raised all point to a failure to canvass or communicate the full range of evidence including data and research findings that go against Key Messages.

- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies without proper analysis of marginal costs and benefits. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem – their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus in the review on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an editorial that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 to be scientifically inadequate and unsuitable as a basis for decision-making, one can imagine a different National Climate Assessment that meets statutory and policymaker requirements. The goal should be not to persuade, but to impart understanding by being transparent and complete. A suitable NCA would be an important complement to IPCC work; to the extent that its conclusions differed from the oracular “consensus” of the IPCC reports and additional topics are addressed, it would promote a more open scientific discussion and a more informed policy debate.

We recommend that the NCA6 have a narrower scope than NCA5, refocusing on climate science including natural climate variability, with topics to include:

- How the climate has changed, or not, in the distant and recent past
 - The U.S. has the best and longest meteorological records and they should be displayed in their entirety. Trend analyses should include longest periods available and employ statistical methods suitable for such datasets. Local paleoclimate data should be considered where available. Analysis would demonstrate not only how the climate has changed, but also the regional heterogeneity. Standard, easily understandable metrics should be employed.

- The range of climatic and weather conditions, including weather extremes, that can reasonably be expected to occur in U.S. regions over the near future for which planners and policymakers should be prepared.
- A critical survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. This would include an assessment of their ability to reproduce observed changes. It would also discuss alternative methods where feasible for generating projections and forecasts on regional and decadal scales. Chapter 10 of the IPCC AR6 WGI provides a reasonable basis. NOTE I HAVE A LOT OF MATERIAL ON THIS
- Potential impacts of future changes on ecosystems and society. Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable trend of a regional change, regional projections using climate models and storyline approaches can be used, targeted at the period 2030-2050. Emissions scenarios exceeding RCP4.5/SSP2-4.5 and models with ECS values > 4°C should not be used

It would also be important to work at a level of detail appropriate to current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to regional and sectoral impacts have little value. It would have been simpler and more accurate to say “we can’t predict at that level.”

In view of the substantial deficiencies in NCA5 that we have outlined, along with the endemic bias of the climate community towards alarmism and policy advocacy, producing NCA6 with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the selected participants reflect full viewpoint diversity and do not simply mirror the assumptions and biases of past NCA teams. We believe the CWG25 report to be a good start in terms of coverage, depth, and tone. It is certainly not the last word and will be subject to public comment and appropriate revisions.

More broadly, we recommend a refresh rewrite of the Global Change Research Act. The current mandate is vague and off point, allowing successive NCA teams to reinterpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. And the use of the term “global change” is ambiguous and outdated.

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APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: Reproducibility of NCA5 claim of extreme precipitation trends

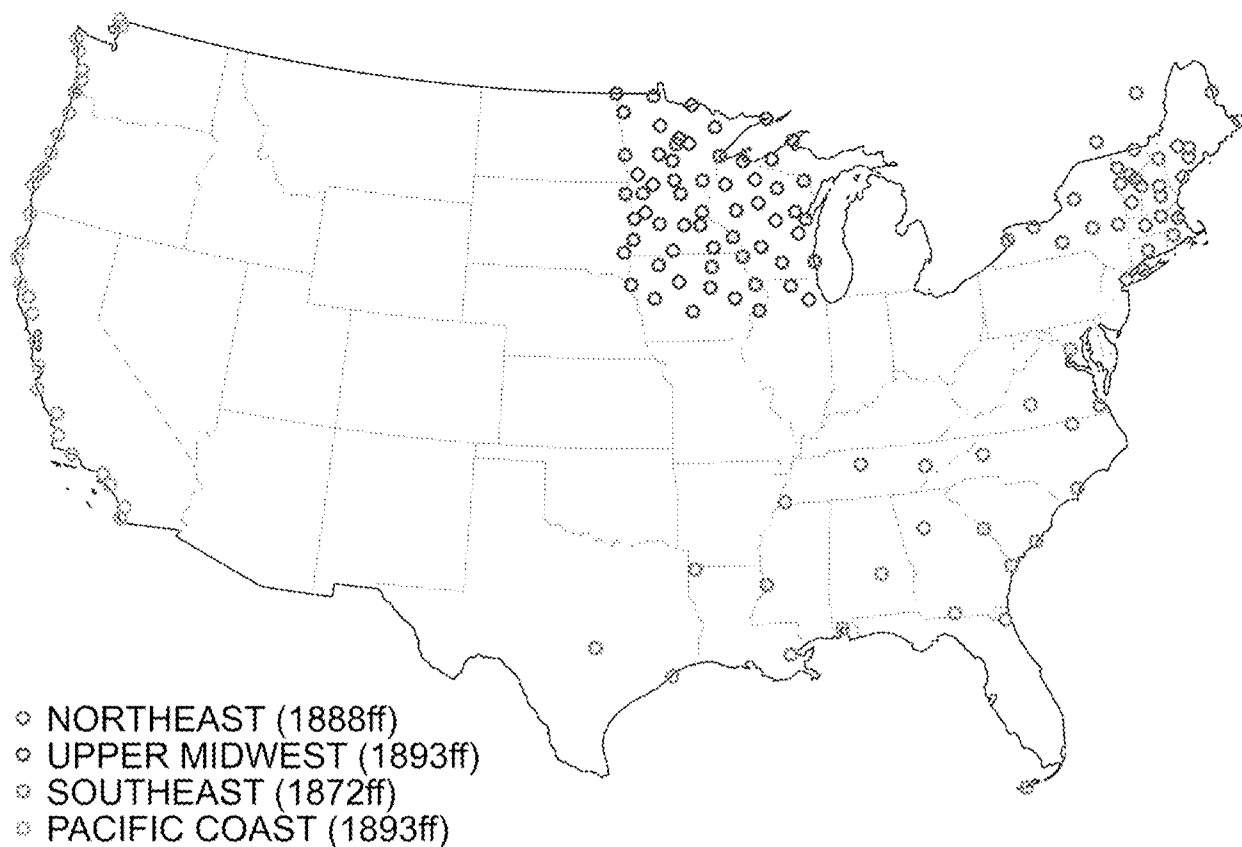


Figure A1: Stations used in the following analyses

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019), code available at McKittrick and Christy (2025).

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure
Column 2: Number of stations in that region
Column 3: Count of stations exhibiting a significant positive trend
Column 3: Count of stations exhibiting a significant negative trend
Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

ABOUT THE AUTHORS

[Insert updated bios]

From: John Christy <climateman60@gmail.com>
Sent: Sunday, June 22, 2025 12:33 PM
To: Steven Koonin
Cc: Judith Curry; Travis Fisher; Roy Spencer; Ross McKittrick; Josh Loucks; Seth Cohen
Subject: Re: Summary chapter

Steve

I'm trying to handle this from my phone, so a little rough. Your red-letter question about NCA's incorporation of alternative views is no problem. I have a few of the public comment submissions that were ignored, including separate submissions by Ross and myself. When I'm back in the office, I can find those. I'm wondering if we can find any information on NCA5's response to our submissions?

It may be enlightening to add the phrase after your point about ignoring comments (I can't remember your exact words), "including public comment submissions by two CWG25 authors"

John C.

Sent from my iPhone

On Jun 22, 2025, at 6:42 AM, Steven Koonin <steven.koonin@gmail.com> wrote:

I've now built on Judy's summary chapter 8, rationalizing it with Section 1.3. Note particularly the recommendations for NCA6.

Also made a start on Chapter 7.

Both are included in the integrated draft attached, which you are urged to read/comment/edit.

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, June 21, 2025 10:32 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Cohen, Seth <seth.cohen@hq.doe.gov>
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Draft of summary chapter is attached, with short recommendations section (cleaned up from yesterday's version). I look forward to your feedback

Below is the recommendations section that I came up with, I'm sure this will be controversial but it will at least trigger the group thinking about the issue:

Recommendations

In view of the substantial problems with NCA5 in failing to comply with the USGCRP mandate and the tenets of Gold Standard Science, along with the endemic bias in the climate community towards alarmism and policy advocacy on the issue of climate change, we do not see a clear path forward for the NCA6 at this time.

The USGCRP mandate to the NCA should be revisited. The current mandate is vague and off point, and it is not entirely surprising that successive NCA teams have interpreted the mandate differently. With regards to specific wording in the mandate, the term "global change" is ambiguous and outdated; it is no longer used in most climate-related documents. It is becoming increasingly clear that climate models are not fit-for-purpose for making regional projections 25 and 100 years in advance.

There are three fundamental issues to be addressed in the near term to support the USGCRP and federal policy making:

- Review of climate science (we suggest that the CWG25 Report meets this objective)
- Comprehensive risk assessment of extreme weather and climate events
- Evaluation of USGCRP portfolio of funded projects and recommendations for the future.

SOMETHING ABOUT ENERGY POLICY???

<~WRD2957.jpg>

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<01.NCA5.Review.June20[JC][SEK].docx>

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Sent: 6/22/2025 3:07:02 PM
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CC: Travis Fisher [travis.scott.fisher@gmail.com]; Roy Spencer [roywspencer@hotmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climatemanager60@gmail.com]; Josh Loucks [loucksj14@gmail.com]; Cohen, Seth [seth.cohen@hq.doe.gov]
Subject: Re: Summary chapter
Attachments: 01.NCA5.Review.June20[JC][SEK] CURRY.docx

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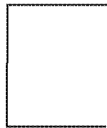
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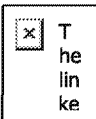
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SOMETHING ABOUT ENERGY POLICY???



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Review of the Fifth National Climate Assessment

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EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, Restoring Gold Standard Science. It enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

Good climate and energy policies should balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by operational demands and the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character, with greater uncertainties and hence need for expert judgement.

For those reasons, assessments of climate science that will be influential for policy making must include statements about the strength of knowledge. The IPCC's approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management (Aven 2017). Here are its elements:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

1.4 When Peer Review Fails

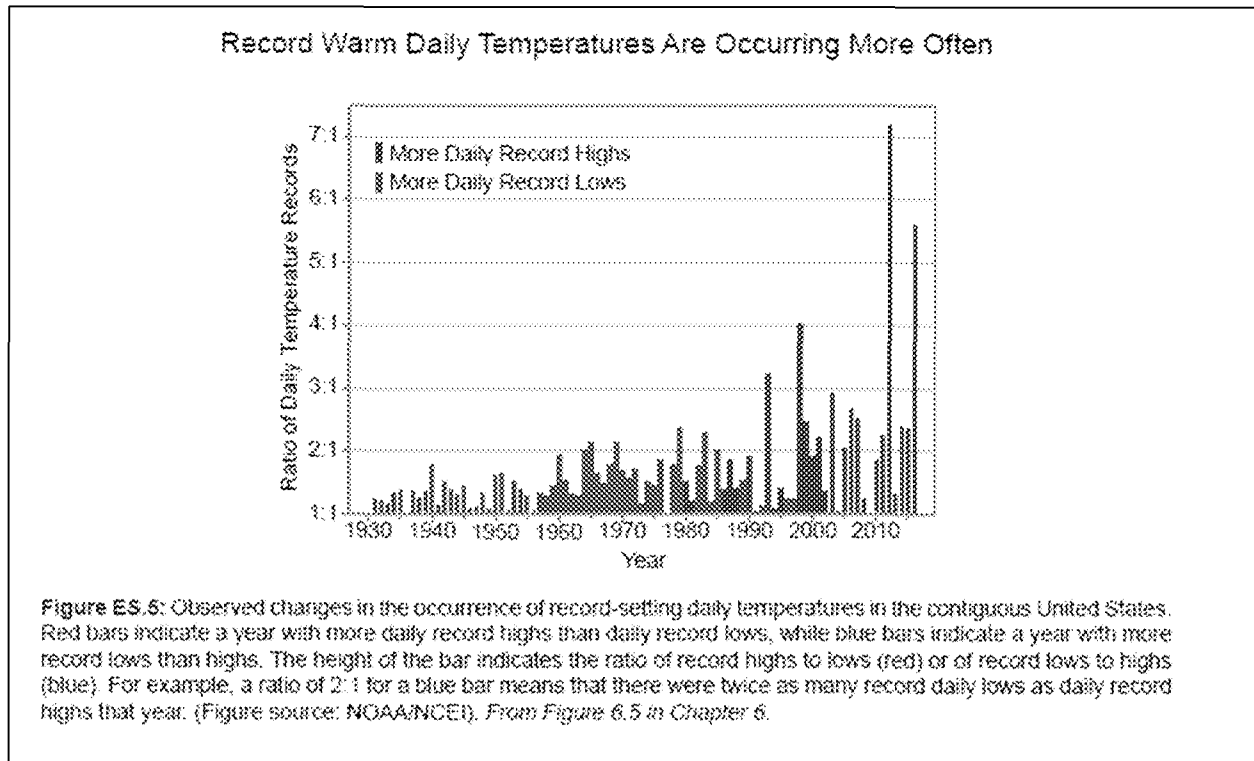
Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

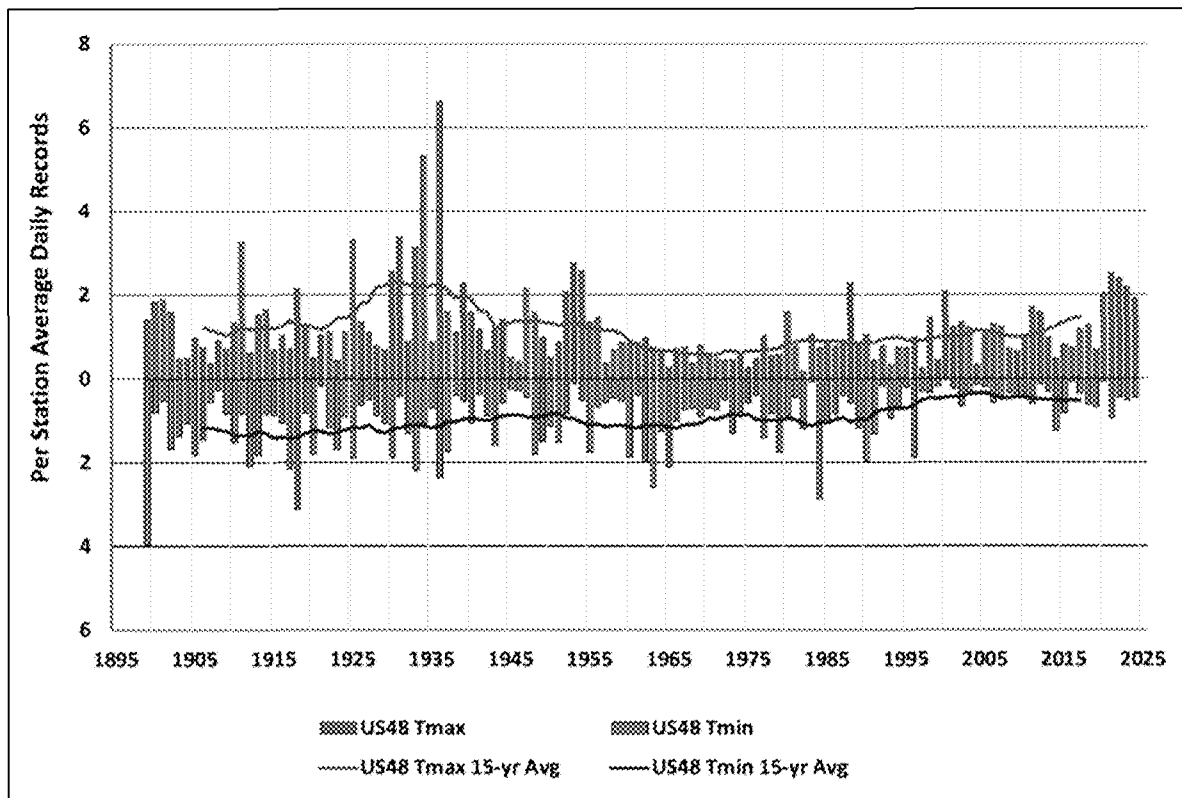


The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast,

25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel criticized the discussion of temperature extremes in a late draft of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) responded to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, “Overview”, holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with -- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5’s use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to “climate change”:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The change metric in NCA5 Figure 2.4 is non-standard; we will discuss NCA5’s inconsistent choices of time scales of analysis below. The claims were attributed to Knutson and Zeng (2018). But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 (Fig. 5) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories –3, –2,

+2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were anthropogenic. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly

influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models increased the uncertainty of ECS, rather than narrowing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

4 RELIANCE ON SHORT TIME PERIODS FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here are some examples of this problem from NCA5.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both

considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. We extended the data used in CWG25 (McKittrick and Christy 2025) to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). See details in Appendix 3. Many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find locations that support the NCA5 position, such as the Southeast post-1950, but results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions.

The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

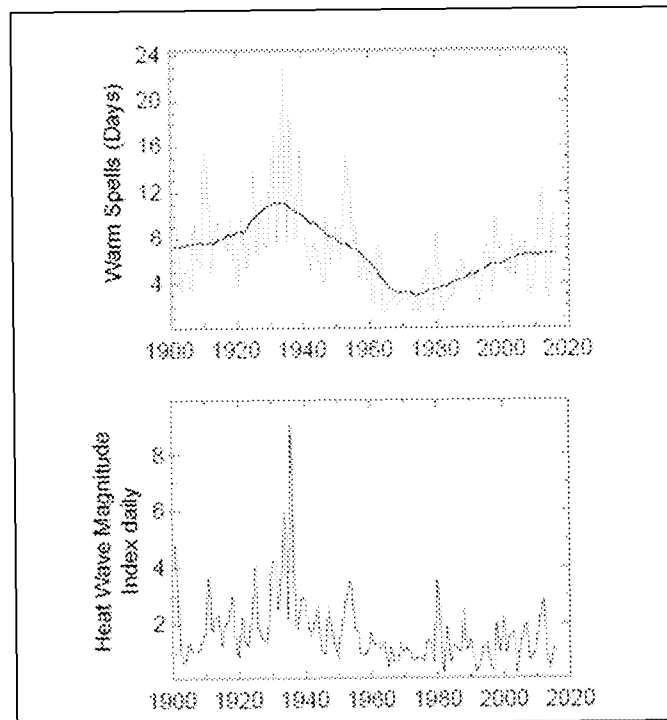
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

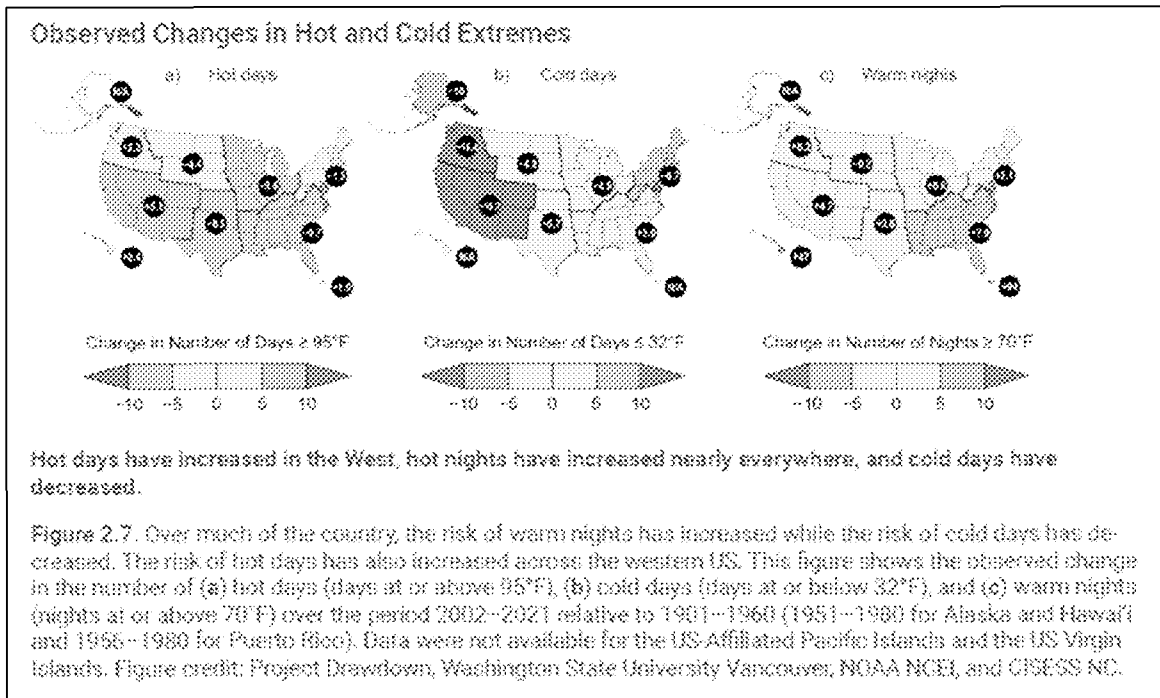
Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-

1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West NCA5 fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that

“multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the eyeball icon does not reveal the metadata information, instead a "Contact Us" email appears, addressed to the USGCRP. This is clearly an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.*						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

[I’ve made a start here – others need to weigh in]

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

NCA5’s use of the term “climate change” is ambiguous

As a result, NCA5’s attribution of various climate trends to “climate change” is misleadingly ambiguous. Consider its statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem, and it could have been easily addressed by adopting the phrase "changing climate" for general changes while reserving the term "climate change" for anthropogenic changes. But the NCA5 authors seemingly ignored their recommendation.

Here are some other examples where NCA5 had problems with natural variability ...

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, Chapter 2 did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed out (Section 4.2) that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title

of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5’s use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP’s charge: whether NCA5 (1) complied with the USGCRP’s statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refers to specific sections of this report as well as to the CWG25 Report.

8.1 Compliance with USGCRP’s statutory obligation

As cited in Section 1.2 of this Report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

With respect to these requirements, we have identified the following major shortcomings in NCA5 (each is detailed in the chapters cited):

- Inadequate assessment of the core of climate science and the hazard components of climate impacts. NCA5 instead focuses on evaluation of societal vulnerabilities, “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Sections 3.1,5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter x **NEW**)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)

- Uncritical evaluation of emission scenarios and climate simulations in making projections for the next 25 to 100 years (Chapter 6; Chapter xx in CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the Chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review evidently lacked the rigor expected of Academies’ reports. (Section 1.4, NEW CHAPTER)

8.3 Suitability for informing Federal climate and energy policy

We assess NCA5 against the knowledge characterizations for risk management (Aven 2017) listed in Section 1.3. For each of the elements, here is specific example where NCA5 falls short:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios
- The degree to which data/information exists and are reliable and relevant
 - NCA5’s assessment of data quality and selection of short time periods for analysis does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, there is no obvious evidence of skeptical voices (such as those who authored this report) being included in the assessment or NASEM review process

[can we really say this with confidence?] [C I TONED IT DOWN]

- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem – their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus in the review on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an editorial that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 to be unsuitable, one can imagine a suitable National Climate Assessment that would inform decision makers and the public with U.S. perspective. The goal should be not to persuade, but to impart understanding by being transparent and complete. A suitable NCA would be an important complement to IPCC work; to the extent that its conclusions differed from the oracular “consensus” of the IPCC reports and additional topics are addressed, it would promote a more open scientific discussion and a more informed policy debate.

We recommend that have a narrower scope than NCA5, refocusing on climate science including natural climate variability, with topics to include:

- How the climate has changed in the distant and recent past
 - The U.S. has the best and longest meteorological records and they should be displayed in their entirety. Trend analyses should include longest periods available. Local paleoclimate data should be considered where available. Analysis would demonstrate not only how the climate has changed, but also the regional heterogeneity. Standard, easily understandable metrics should be employed.
- How might climate change in the future

- A survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. Assess their ability to reproduce observed changes, as well as their projections under various emissions scenarios. Consider alternative methods for generating future scenarios on regional and decadal scales. Chapter 10 of the IPCC AR6 WGI provides a reasonable basis ~~NOTE I HAVE A LOT OF MATERIAL ON THIS~~
- ~~Potential impacts of future changes on ecosystems and society~~ Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable trend of a regional change, regional projections using climate models and storyline approaches can be used, targeted at the period 2030-2050. When using climate models, emissions scenarios exceeding RCP4.5/SSP2-4.5 and ECS values > 4C should not be used

~~In covering projected changes and impacts, it would be important to use only plausible emissions scenarios and models with plausible sensitivities; demonstrably oversensitive models run with demonstrably extreme scenarios feed the “could be as bad as” meme but undermine responsible policymaking. ACTUALLY I THINK WE SHOULD DROP USING FUTURE REGIONAL PROJECTIONS~~

It would also be important to work at a level of detail appropriate to current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to regional and sectoral impacts have little value. It would have been simpler and more accurate to say “we can’t predict at that level.”

In view of the substantial deficiencies in NCA5 that we have outlined, along with the endemic bias of the climate community towards alarmism and policy advocacy, producing NCA6 with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the review is rigorous and complete and NCA6 authors are required respond substantively. We believe our CWG25 report to be a good start, exemplifying suitable coverage, depth, and tone. It is certainly not the last word and will be subject to public comment and appropriate revisions.

~~[can we offer some positive recommendations for going forward? say red team or competing reviews]~~

More broadly, we recommend a refresh of the Global Change Research Act that mandates a quadrennial NCA. The current mandate is vague and off point, giving successive NCA teams freedom to interpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. And the use of the term “global change” is ambiguous and outdated.

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APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: Reproducibility of NCA5 claim of extreme precipitation trends

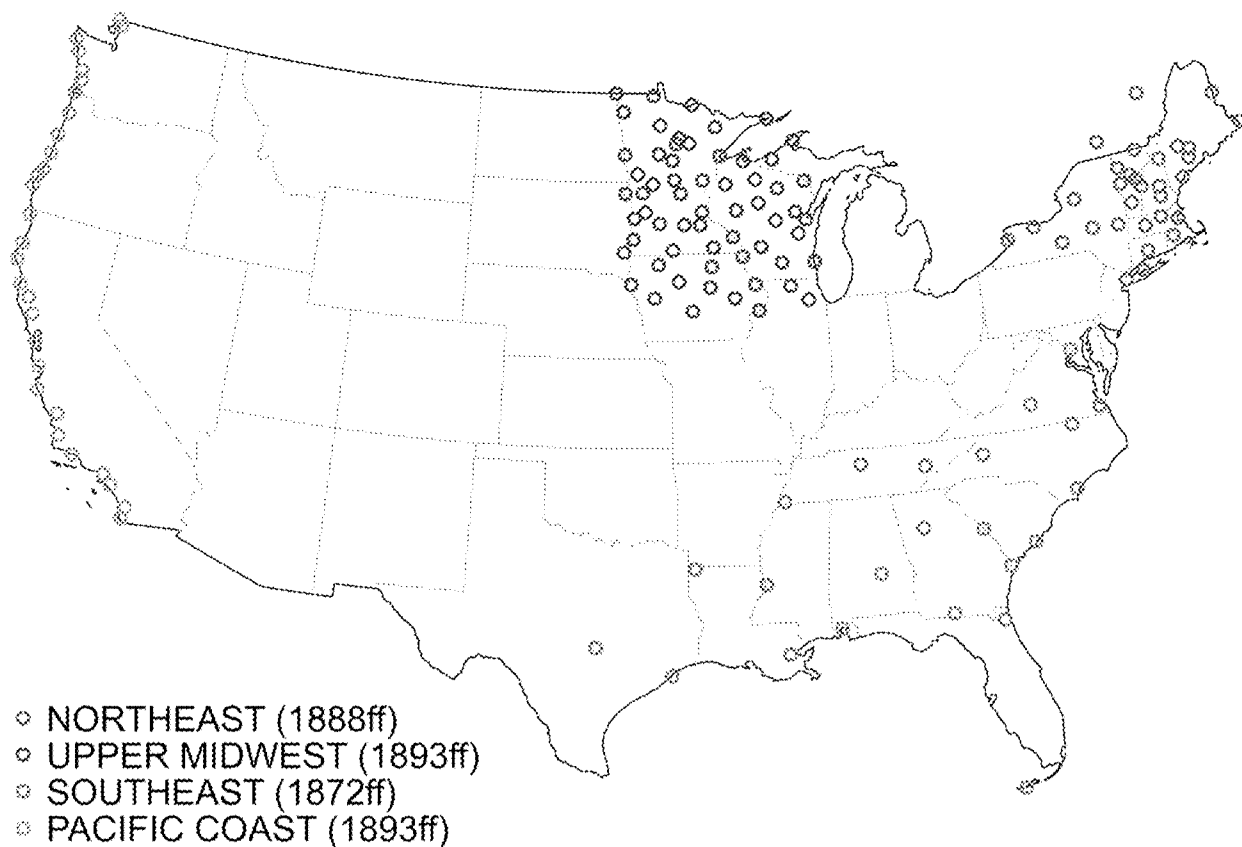


Figure A1: Stations used in the following analyses

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019), code available at McKittrick and Christy (2025).

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

ABOUT THE AUTHORS

[Insert updated bios]

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Sunday, June 22, 2025 10:42 AM
To: 'Judith Curry'
Cc: 'Travis Fisher'; 'Roy Spencer'; 'Ross McKittrick'; 'John Christy'; 'Josh Loucks'; 'Cohen, Seth'
Subject: RE: Summary chapter
Attachments: ~WRD2957.jpg; 01.NCA5.Review.June20[JC][SEK].docx

I've now built on Judy's summary chapter 8, rationalizing it with Section 1.3. Note particularly the recommendations for NCA6.

Also made a start on Chapter 7.

Both are included in the integrated draft attached, which you are urged to read/comment/edit.

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, June 21, 2025 10:32 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Cohen, Seth <seth.cohen@hq.doe.gov>
Subject: Summary chapter

Draft of summary chapter is attached, with short recommendations section (cleaned up from yesterday's version). I look forward to your feedback

Below is the recommendations section that I came up with, I'm sure this will be controversial but it will at least trigger the group thinking about the issue:

Recommendations

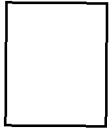
In view of the substantial problems with NCA5 in failing to comply with the USGCRP mandate and the tenets of Gold Standard Science, along with the endemic bias in the climate community towards alarmism and policy advocacy on the issue of climate change, we do not see a clear path forward for the NCA6 at this time.

The USGCRP mandate to the NCA should be revisited. The current mandate is vague and off point, and it is not entirely surprising that successive NCA teams have interpreted the mandate differently. With regards to specific wording in the mandate, the term "global change" is ambiguous and outdated; it is no longer used in most climate-related documents. It is becoming increasingly clear that climate models are not fit-for-purpose for making regional projections 25 and 100 years in advance.

There are three fundamental issues to be addressed in the near term to support the USGCRP and federal policy making:

- Review of climate science (we suggest that the CWG25 Report meets this objective)
- Comprehensive risk assessment of extreme weather and climate events
- Evaluation of USGCRP portfolio of funded projects and recommendations for the future.

SOMETHING ABOUT ENERGY POLICY???



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Review of the Fifth National Climate Assessment

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EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, Restoring Gold Standard Science. It enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

Good climate and energy policies should balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by operational demands and the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character, with greater uncertainties and hence need for expert judgement.

For those reasons, assessments of climate science that will be influential for policy making must include statements about the strength of knowledge. The IPCC's approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management (Aven 2017). Here are its elements:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

1.4 When Peer Review Fails

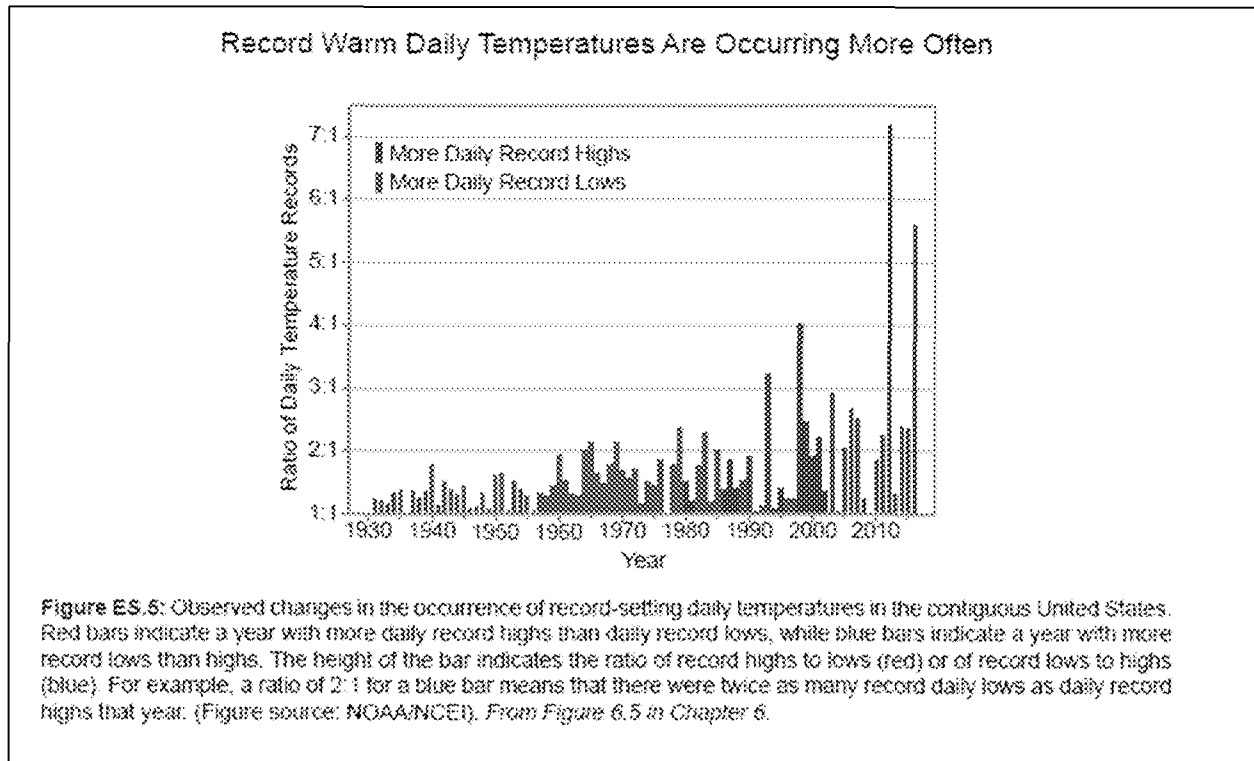
Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

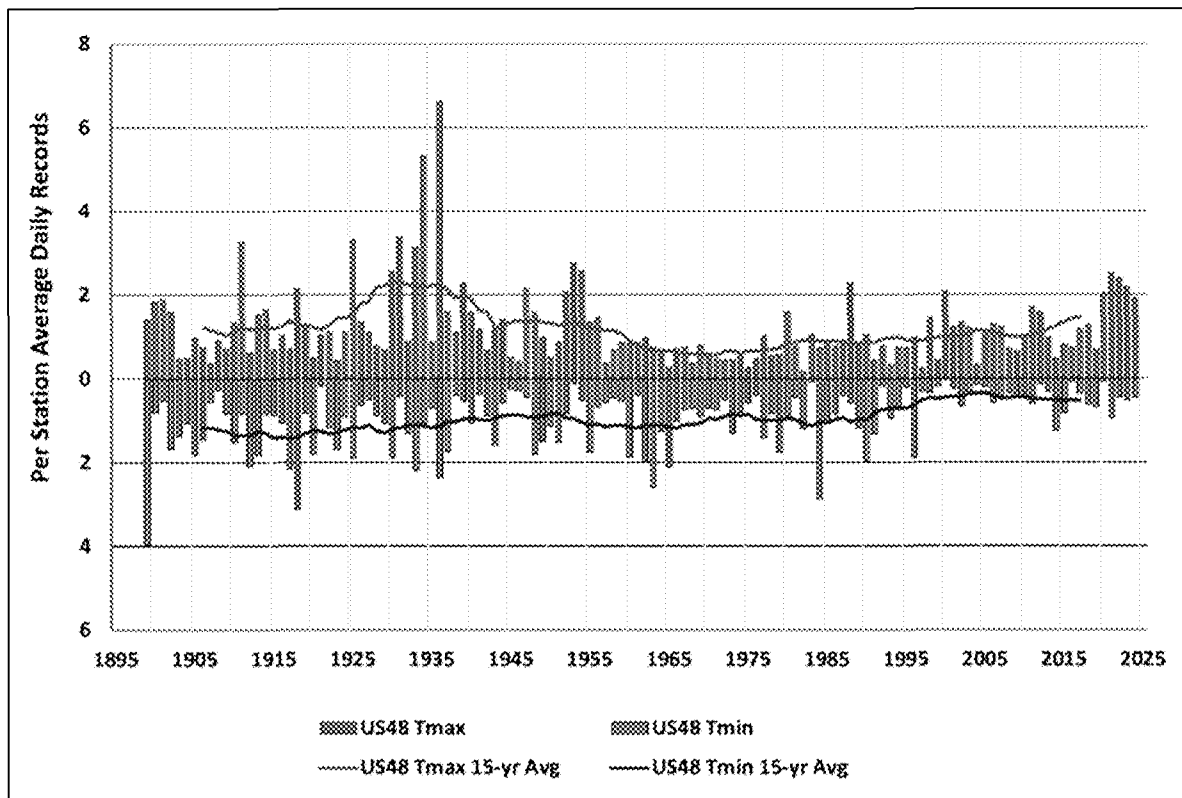


The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast,

25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel criticized the discussion of temperature extremes in a late draft of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) responded to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, “Overview”, holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with -- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits...”

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: “Climate modeling experts develop global climate projections for a range of plausible futures.” The word “plausible” is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as “plausible” the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline “business-as-usual” future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying “Harmful impacts from more frequent and severe extremes are increasing across the country.” This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5’s use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to “climate change”:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The change metric in NCA5 Figure 2.4 is non-standard; we will discuss NCA5’s inconsistent choices of time scales of analysis below. The claims were attributed to Knutson and Zeng (2018). But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 (Fig. 5) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories –3, –2,

+2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were anthropogenic. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly

influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models increased the uncertainty of ECS, rather than narrowing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

4 RELIANCE ON SHORT TIME PERIODS FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here are some examples of this problem from NCA5.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both

considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. We extended the data used in CWG25 (McKittrick and Christy 2025) to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). See details in Appendix 3. Many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find locations that support the NCA5 position, such as the Southeast post-1950, but results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions.

The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

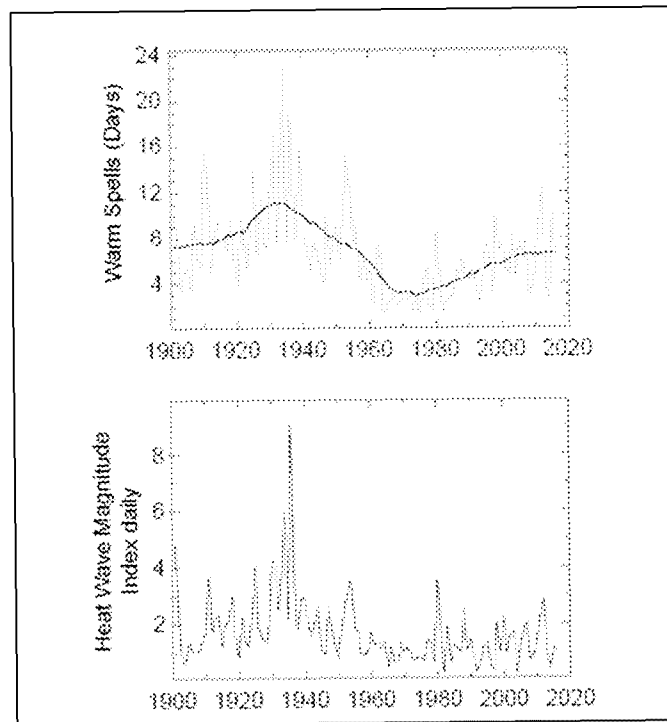
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

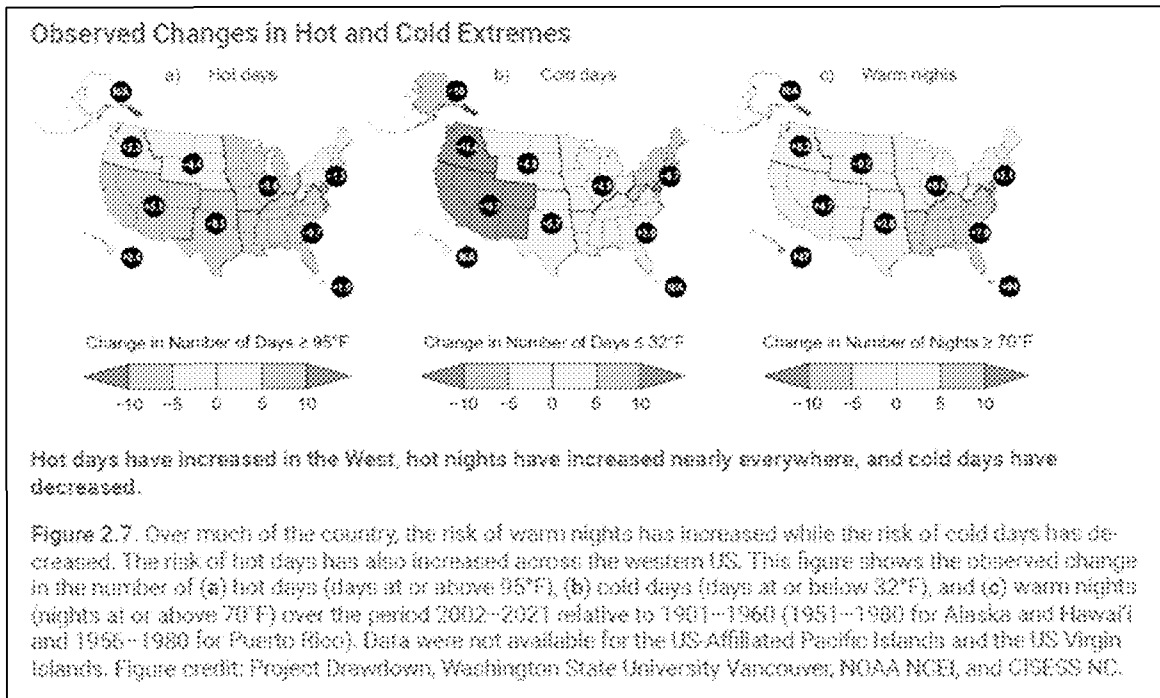
Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-

1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West NCA5 fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that

“multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the eyeball icon does not reveal the metadata information, instead a "Contact Us" email appears, addressed to the USGCRP. This is clearly an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.*						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

[I’ve made a start here – others need to weigh in]

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

NCA5’s use of the term “climate change” is ambiguous

As a result, NCA5’s attribution of various climate trends to “climate change” is misleadingly ambiguous. Consider its statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem, and it could have been easily addressed by adopting the phrase "changing climate" for general changes while reserving the term "climate change" for anthropogenic changes. But the NCA5 authors seemingly ignored their recommendation.

Here are some other examples where NCA5 had problems with natural variability ...

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, Chapter 2 did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed out (Section 4.2) that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title

of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5’s use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP’s charge: whether NCA5 (1) complied with the USGCRP’s statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refers to specific sections of this report as well as to the CWG25 Report.

8.1 Compliance with USGCRP’s statutory obligation

As cited in Section 1.2 of this Report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

With respect to these requirements, we have identified the following major shortcomings in NCA5 (each is detailed in the chapters cited):

- Inadequate assessment of the core of climate science and the hazard components of climate impacts. NCA5 instead focuses on evaluation of societal vulnerabilities, “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Sections 3.1,5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter x **NEW**)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)

- Uncritical evaluation of emission scenarios and climate simulations in making projections for the next 25 to 100 years (Chapter 6; Chapter xx in CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the Chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review evidently lacked the rigor expected of Academies’ reports. (Section 1.4, NEW CHAPTER)

8.3 Suitability for informing Federal climate and energy policy

We assess NCA5 against the knowledge characterizations for risk management (Aven 2017) listed in Section 1.3. For each of the elements, here is specific example where NCA5 falls short:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios
- The degree to which data/information exists and are reliable and relevant
 - NCA5’s assessment of data quality and selection of short time periods for analysis does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, skeptical voices (such as those who authored this report) were not included in the assessment or NASEM review process

[can we really say this with confidence?]

- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem – their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus in the review on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an [editorial](#) that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 unsuitable, one can imagine a suitable National Climate Assessment that would inform decision makers and the public with U.S. perspective. The goal would be not to persuade, but to impart understanding by being transparent and complete. A suitable NCA would be an important complement to IPCC work; to the extent that its conclusions differed from the oracular “consensus” of the IPCC reports, it would promote a more open scientific discussion and a more informed policy debate.

NCA6 have a narrower scope than NCA5, refocusing on climate science, with topics to include:

- How has the climate changed in the distant and recent past
 - The U.S. has the best and longest meteorological records and they should be displayed in their entirety. Trend analyses should include longest periods available. Analysis would demonstrate not only how the climate has changed, but also the regional heterogeneity. Standard, easily understandable metrics should be employed.
- How might it change in the future
 - A survey of current modeling capabilities, including their ability to reproduce observed changes, as well as their projections under various emissions scenarios.
- what might be the impacts of future changes on ecosystems and society

In covering projected changes and impacts, it would be important to use only plausible emissions scenarios and models with plausible sensitivities; demonstrably oversensitive models run with demonstrably extreme scenarios feed the “could be as bad as” meme but undermine responsible policymaking.

It would also be important to work at a level of detail appropriate to current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to regional and sectoral impacts have little value. It would have been simpler and more accurate to say “we can’t predict at that level.”

In view of the substantial deficiencies in NCA5 that we have outlined, along with the endemic bias of the climate community towards alarmism and policy advocacy, producing NCA6 with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the review is rigorous and complete and NCA6 authors are required respond substantively. We believe our CWG25 report to be a good start, exemplifying suitable coverage, depth, and tone. It is certainly not the last word and will be subject to public comment and appropriate revisions.

[can we offer some positive recommendations for going forward? say red team or competing reviews]

More broadly, we recommend a refresh of the Global Change Research Act that mandates a quadrennial NCA. The current mandate is vague and off point, giving successive NCA teams freedom to interpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. And the use of the term “global change” is ambiguous and outdated.

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APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: Reproducibility of NCA5 claim of extreme precipitation trends

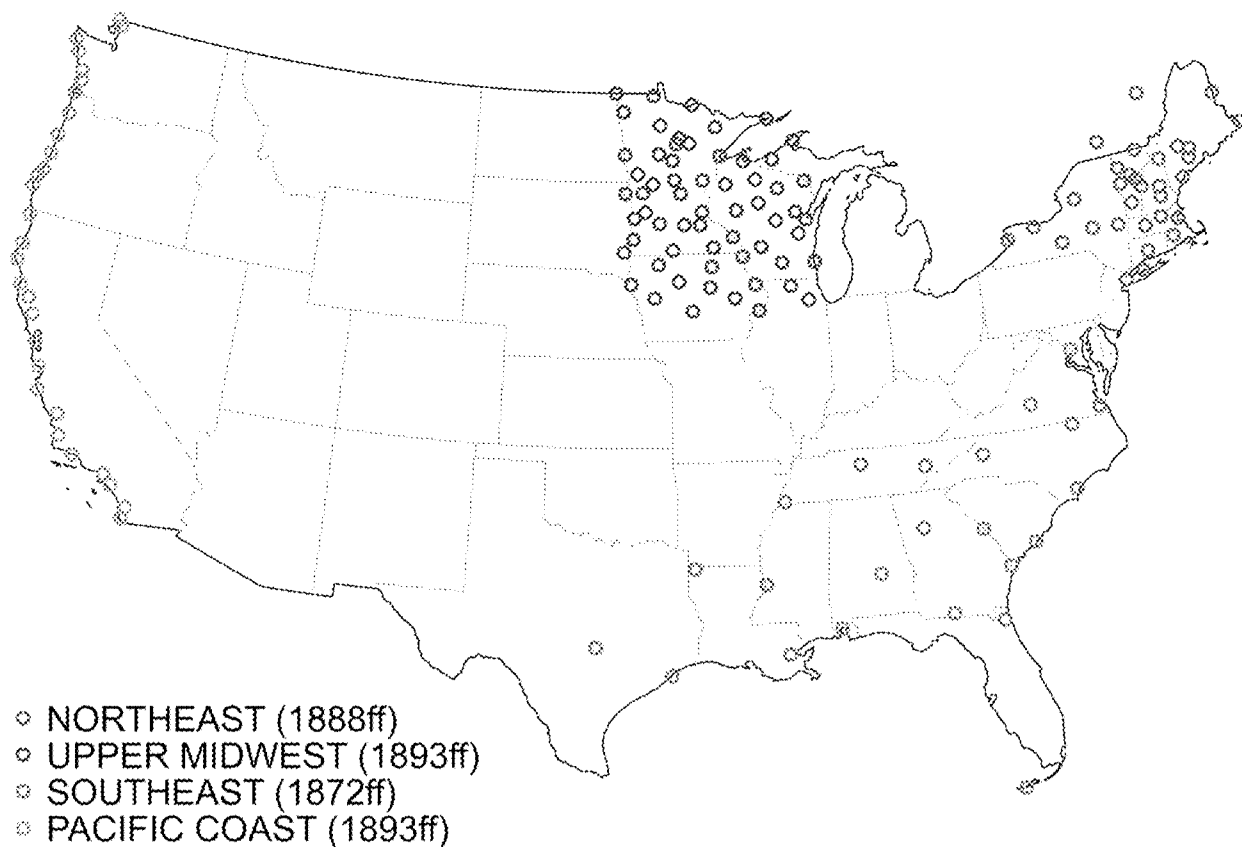


Figure A1: Stations used in the following analyses

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019), code available at McKittrick and Christy (2025).

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

ABOUT THE AUTHORS

[Insert updated bios]

From: Roy Spencer [roywspencer@hotmail.com]
Sent: 6/21/2025 5:15:22 PM
To: Judith Curry [curry.judith@gmail.com]; Steven Koonin [steven.koonin@gmail.com]
CC: Travis Fisher [travis.scott.fisher@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climateman60@gmail.com]; Josh Loucks [loucksj14@gmail.com]; Cohen, Seth [seth.cohen@hq.doe.gov]
Subject: Re: Summary chapter

I like this.
-Roy

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, June 21, 2025 9:31 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Cohen, Seth <seth.cohen@hq.doe.gov>
Subject: Summary chapter

Draft of summary chapter is attached, with short recommendations section (cleaned up from yesterday's version). I look forward to your feedback

Below is the recommendations section that I came up with, I'm sure this will be controversial but it will at least trigger the group thinking about the issue:

Recommendations

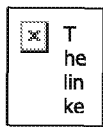
In view of the substantial problems with NCA5 in failing to comply with the USGCRP mandate and the tenets of Gold Standard Science, along with the endemic bias in the climate community towards alarmism and policy advocacy on the issue of climate change, we do not see a clear path forward for the NCA6 at this time.

The USGCRP mandate to the NCA should be revisited. The current mandate is vague and off point, and it is not entirely surprising that successive NCA teams have interpreted the mandate differently. With regards to specific wording in the mandate, the term "global change" is ambiguous and outdated; it is no longer used in most climate-related documents. It is becoming increasingly clear that climate models are not fit-for-purpose for making regional projections 25 and 100 years in advance.

There are three fundamental issues to be addressed in the near term to support the USGCRP and federal policy making:

- Review of climate science (we suggest that the CWG25 Report meets this objective)
- Comprehensive risk assessment of extreme weather and climate events
- Evaluation of USGCRP portfolio of funded projects and recommendations for the future.

SOMETHING ABOUT ENERGY POLICY???



Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
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<http://www.cfanclimate.net>

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, June 21, 2025 10:32 AM
To: Steven Koonin
Cc: Travis Fisher; Roy Spencer; Ross McKittrick; John Christy; Josh Loucks; Cohen, Seth
Subject: Summary chapter
Attachments: summary:conclusions (2).docx

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1 SUMMARY EVALUATION OF NCA5

This Chapter presents a summary evaluation relative to the charge we received from the OSTP: whether NCA5 (1) complied with the USGCRP's statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refers to specific sections of this report as well as to the CWG25 Report.

1.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this Report, the NCA Reports have a statutory obligation to prepare an assessment which:

- (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

With respect to these obligations, we have identified the following major shortcomings in NCA5:

- Failure to assess adequately the core of climate science and the hazard elements of climate impacts. Instead, the NCA5 focuses on evaluation of societal vulnerabilities, "Climate Action," and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainty (Sections 3.1, 5)
- Failure to adequately discriminate between natural and human-induced causes of trends and impacts (Chapter x ~~NEW~~)
- Failure to adequately analyze current trends owing to reliance on short time periods for trend analysis (Chapter 6)
- Failure to critically evaluate emission scenarios and climate model simulations in making projections for the next 25 to 100 years (Chapter 6; Chapter xx in CWG25).

1.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

We have identified the following major shortcomings in the NCA5:

- Lack of reproducibility. In the few examples that we examined closely, we identified one instance where we could not reproduce the findings of the NCA5 that should require only rudimentary data analysis (Section 4.1)
- Lack of transparency. In many instances, the Traceable Account fails to provide the appropriate justification for the Key Finding. Metadata was not readily accessible. (Chapter 5)
- Inadequate communicative of error and uncertainty. The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- Not skeptical of findings and assumptions. The main text of the Chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- Some hypotheses and Key Messages are not falsifiable. Here is one of many such examples: “Key Message 13.4 Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (REFER TO CWG25)
- Inadequacy of the peer review process. The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023). While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading “Comments on Equity and Justice”), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. (Section 1.4, NEW CHAPTER)

1.3 Suitability for informing federal climate and energy policy

When scientific reports are being assembled that will be highly influential on policymaking, there are other desiderata (beyond the issues mentioned in sections 1 and 2 above), including statements about the strength of knowledge. The IPCC’s approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include those provided by risk scientist Terje Aven (Aven 2017). The following elements are enumerated, with specific examples where NCA5 falls short in its knowledge characterization:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about NCA5 focus on implausible extreme emissions and sea level rise scenarios
- The degree to which data/information exists and are reliable and relevant—NCA5 assessment of data quality and selection of short time periods for analysis falls does not support conclusions with high confidence.
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—while the NCA5 is an interdisciplinary effort, skeptical

voices (such as the authors of this Report) were not included in the assessment or NASEM review process.

- The degree to which the phenomena involved are understood and accurate models exist—the NCA5 did not express appropriate levels of skepticism about climate models for purposes of attribution of the causes of warming and extreme events or for future projections.
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—the most obvious NCA5 shortcoming in this regard is relative neglect of natural climate variability

NCA5 is further problematic as a document to inform policy making because of the hyperbolic language employed to promote alarm and to advocate for specific policies. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem – their review appears to be written by authors who share many of the biases of the NCA5 team with an inordinate focus in the review on social and policy issues.

So it is not surprising that objectivity suffers when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

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SOMETHING ABOUT ENERGY POLICY???

From: John Christy <climateman60@gmail.com>
Sent: Saturday, June 14, 2025 11:38 AM
To: Steven Koonin
Cc: Judith Curry; Ross McKittrick; Roy W. Spencer; Travis Fisher
Subject: Re: S7 on climate action and health

They lost me at “profoundly”.

John C.

Sent from my iPhone

> On Jun 13, 2025, at 4:39 PM, Steven Koonin <steven.koonin@gmail.com> wrote:
>
> If you've not yet seen- SEK
>
> <https://www.nasonline.org/wp-content/uploads/2025/06/Climate-Action.pdf>
>
>
> <Climate-Action.pdf>
>
> Steven E. Koonin
>

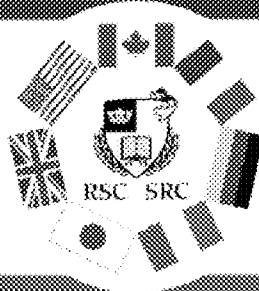
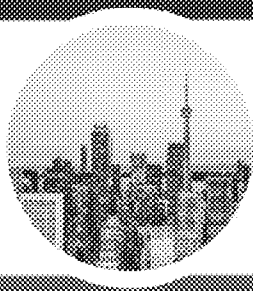
From: Steven Koonin [steven.koonin@gmail.com]
Sent: 6/14/2025 12:39:42 AM
To: Judith Curry [curry.judith@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climatemanager60@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: S7 on climate action and health
Attachments: Climate-Action.pdf; Untitled attachment.txt

If you've not yet seen- SEK

<https://www.nasonline.org/wp-content/uploads/2025/06/Climate-Action.pdf>

S7

#S7CANADA



ADVANCING SCIENCE FOR SOCIETY: HEALTH, MIGRATION AND TECHNOLOGIES 2025 SUMMIT OF THE S7 ACADEMIES | MAY 6-8 2025 | OTTAWA, ONTARIO, CANADA CLIMATE ACTION AND HEALTH RESILIENCE

DEFINING THE ISSUE

Climate change is profoundly harming health through its impacts on human and natural systems, and risks undermining health progresses achieved in previous decades. Widespread and rapid changes in the Earth's climate system harm the health of people, animals and ecosystems and the resilience of health and social services¹. Heat waves are increasing illnesses and deaths globally. More frequent and intense climate events drive population displacement, food and water insecurity, and undernutrition through disruptions to agricultural and food systems. Changing temperatures and biodiversity losses are making more areas hospitable for vector-borne and zoonotic disease transmission by altering insect and wildlife habitats, driving the spread of diseases like dengue and malaria to new regions, and increasing risks of epidemics and pandemics. Growing wildfire-related atmospheric pollution caused by global warming is worsening chronic illness and death from cardiovascular and respiratory diseases, while earlier spring pollen seasons in northern latitudes are increasing risks of allergic respiratory diseases. Mental health challenges are increasing through the trauma and psychological stresses of climate change-related loss of homes, livelihoods, or culture. Heat has direct effects on the nervous and endocrine systems and extreme weather events have indirect psychosocial consequences. Climate change impacts are not experienced equally by all populations. Women, children and youth, older adults, Indigenous Peoples, low-income households, displaced populations, socially marginalized groups, and people in remote communities, Low- and Middle-Income Countries, and the Small Island Developing States are the most at-risk of immediate health threats and worsening of existing health concerns.

Climate action is urgently needed in response to what the UN has defined as the “Triple Planetary Crisis” of interconnected challenges of climate change, biodiversity loss, and pollution. Leveraging the important health benefits of climate mitigation while strengthening adaptation efforts can minimize immediate and long-term health risks. Health systems are already facing profound challenges. Transformation toward more sustainable, low-carbon, climate-resilient health systems is needed to face the double challenge of reducing the carbon footprint of health facilities, products, and supply chains, while improving their ability to prepare for, recover from, and adapt to climate change impacts.

¹ WHO (2024). *COP29 special report on climate change and health: Health is the argument for climate action*. World Health Organization, Geneva. https://cdn.who.int/media/docs/default-source/environment-climate-change-and-health/cop29-report_summary.pdf?sfvrsn=2556cbaf_7; IPCC (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. <https://www.ipcc.ch/report/ar6/wg2/>; IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. <https://www.ipcc.ch/report/ar6/wg1/>; OECD (2024). *The Climate Action Monitor 2024*, OECD Publishing, Paris. <https://doi.org/10.1787/787786f6-ca>

POLICY RECOMMENDATIONS

RECOMMENDATION 1

Develop and optimize climate change mitigation strategies to maximize transformative health impacts. Reducing greenhouse gas (GHG) emissions from energy, industry, transportation, building sectors, agriculture and food systems can bring enormous health benefits. Some immediate actions include: replace fossil fuels with renewables for energy generation; improve ventilation and insulation of buildings and homes using the passive house concept; employ lower-emissions electric vehicles, public transit, and active transportation; increase consumption of healthy, sustainable diets; and, expand urban green infrastructure. Societal benefits of these actions are fewer deaths, illness, and injuries from extreme weather and air pollution, increased food security, reduced spread of vector-borne diseases to new areas, reduced heat-related mortality, and reduced social and geographic inequities. These health benefits will occur on a shorter timescale than the climate benefits, and will accrue locally even in the absence of strong climate action from other countries in relation to CBDR. Importantly, the health argument for GHG emission reductions could make climate mitigation strategies more desirable and more cost-effective to motivate rapid action.

RECOMMENDATION 2

Support mitigation and adaptation options that mainstream health into biodiversity, food, infrastructure, social protection, and water policies. Climate-resilient agriculture and fisheries can help promote sustainable water and soil management and biodiversity conservation, along with food system transformation to address climate change impacts on food supply and nutrition, improving access to potable water, and reducing exposure of water and sanitation systems to flooding. Ecosystem-based adaptation measures can help safeguard biodiversity and improve ecosystem health. Climate-resilient urban planning (including urban greening and low-carbon transportation networks) can reduce urban heat island effects and improve air quality. Strengthening public health infrastructure, workforce training and capacity, programs, surveillance, and early warning and response systems can help address climate change-related risks and climate-sensitive diseases. Emergency response and recovery planning, evacuation, and shelter provision can address unique challenges faced by underserved populations.

RECOMMENDATION 3

Invest strategically in public health and longevity. Develop new regulations nationally and internationally to facilitate comprehensive transformations of health and social services, increasing their readiness and safeguarding human health from climate change impacts. Reinforcing preventive actions can promote short-term resiliency by alleviating the burden on health systems and longer-term transitions to climate neutrality. Related workforce demands require investments to train healthcare professionals. Strengthening the social safety net through programs and policies that alleviate poverty and protect people from economic shocks helps to secure a livable and sustainable future for all. Adopting a whole-system preparedness approach recognizes health security and the adaptiveness of a nation's socio-economic capacity as essential factors in overall security.

RECOMMENDATION 4

Provide economic and regulatory incentives to foster adaptation, resiliency, and mitigation. Examples of these incentives include reducing taxes or introducing subsidies for new products or technologies that address health impacts of climate change while reducing subsidies and considering a global carbon pricing mechanism and taxation for products that contribute to climate change; working proactively at different levels of government to update and coordinate development, building, or zoning regulations and codes (including planning and construction codes), with consideration of future climate change; supporting the development of occupational safety protocols (through trade deals or supply chain regulations) that address workplace conditions and practices that expose employees to climate change-related risks; and, incentivizing climate change mitigation policies that consider health by promoting them through national and international bodies.

RECOMMENDATION 5

Assess and strengthen climate-resiliency of critical infrastructure, communities, and societies. This includes: strengthening water, sanitation and hygiene infrastructure to protect water safety and security; securing access to key infrastructure and safety shelters, including infrastructure for active transportation; developing relocation plans as a means of last resort (and only implemented with the agreement of affected communities) to protect critical infrastructure and communities with known vulnerabilities, especially in remote areas; designing and retrofitting buildings with low-carbon solutions to enhance indoor air quality, reduce exposure to harmful pollutants, and maintain comfortable

indoor temperatures during extreme heat or cold; and, strengthening the resilience of health systems and public health supply chains to withstand disruptions caused by extreme weather events. Diversifying supply sources, increasing local production capacities, and maintaining strategic reserves of essential medicines, medical supplies, and equipment can maintain the reliability and effectiveness of health systems despite disruptions caused by climate change. Equitably distributed resources for health surveillance, including biomonitoring and genome sequencing, and biomanufacturing for vaccines and treatment technologies, can support One Health and Planetary Health approaches that integrate human, animal, and ecosystem health to better face future pandemics.

RECOMMENDATION 6

Invest in innovative solutions. Increasing investments in knowledge and research driven innovation, generating new approaches to better understand and address risks to health through climate change mitigation, adaptation, and resilience. Also critical are societal and political innovations that involve affected individuals and communities, including Indigenous Peoples, in the definition and co-construction of climate action. Innovative solutions require rigorous data collection, analysis, and sharing on biodiversity, health, socio-economic, and equity impacts of climate change; and, on effectiveness of adaptation and mitigation interventions (e.g., pandemic preparedness, vaccine development for emerging diseases) on ecosystems, health and social systems, and on food, water, and critical infrastructure systems. Policies that foster trans-sectoral collaborations (e.g. between academic institutions, governmental agencies, and private sectors), knowledge mobilization and exchange, and technical capacity building to conduct health analytics, modelling, and intervention implementation relative to climate change, extreme weather events, and emerging diseases provide important foundations to develop innovative climate solutions.

RECOMMENDATION 7

Implement an equity-focused approach in data collection, policy development, and service delivery. Ensuring that climate action policies and health interventions prioritize those at the highest risk of inequities is crucial. This includes adopting inclusive data collection practices that capture the diverse impacts of climate change on communities with known vulnerabilities and those being marginalized or historically overlooked, within and between countries and regions. Policies should be informed by high-quality, appropriately scaled data to identify and address the specific needs of these populations, such as women, children and youth, older adults, Indigenous Peoples, low-income households, people in remote communities, displaced populations, and racialized or socially marginalized groups. Service delivery should be tailored to consider cultural contexts, Indigenous and local knowledges, and involve affected communities in decision-making processes from the beginning. By centering equity, health systems will be better prepared to provide targeted resources and support to those most affected. This will enhance resilience, reduce health disparities, and support the attainment of health-related SDGs.

CANADA

The Royal Society of Canada



ALAIN-G. GAGNON

Alain G. Gagnon

ITALY

Accademia Nazionale dei Lincei



ROBERTO ANTONELLI

Roberto Antonelli

FRANCE

Académie des sciences



ACADEMIE
DES SCIENCES
INSTITUT DE FRANCE

FRANÇOISE COMBES

Françoise Combes

JAPAN

Science Council of Japan



MAMORU MITSUSHI

Mamoru Mitsuishi

UNITED STATES

National Academy of Sciences



MARCIA McNUTT

Marcia McNutt

GERMANY

*German National Academy
of Sciences Leopoldina*



Leopoldina
Nationale Akademie
der Wissenschaften

BETTINA ROCKENBACH

Bettina Rockenbach

UNITED KINGDOM

The Royal Society

THE
ROYAL
SOCIETY

ADRIAN SMITH

Adrian Smith

Steven E. Koonin

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Friday, May 30, 2025 4:16 PM
To: 'Judith Curry'; 'Ross McKittrick'; 'John Christy'; 'Roy Spencer'; 'Josh Loucks'
Subject: a few thoughts on scanning the first chapters of NCA5
Attachments: image003.png

Much of what's written is completely factual but factually incomplete.

1. The ratio of words to figures is far too high for my taste. That creates many opportunities to shade the presentation to alarm without being overtly wrong. Compare two hypothetical phrasings: "sea level is rising!" with "sea level continues to rise at its historical rate"
2. Projections are shown without uncertainties
3. Many of the descriptions compare 2002-2021 observations with those averaged 1901-1960, thereby wiping out the 1930s variability
4. Natural variability is minimized. e.g. "How Much the Climate Changes Depends on the Choices Made Now"
5. [I could go on and on.]

It would be pretty easy to go through and do a paragraph-by-paragraph "yes, but" for the first few chapters, showing up the misrepresentation. Worth it?

Here are some principles for NCA6:

1. Liberal use of figures to show the data
2. Show all the data – rather than cherry pick, take a "whole orchard approach" by not truncating records
3. Show uncertainties in observations, models, projections
4. For big or small numbers quoted, set a scale. For example, on pg 4-18 we find "Between 1980 and 2022, drought and related heatwaves caused \$334.8 billion (in 2023 dollars) in damages..." That is indeed a big number that will impress the innumerate (and I'm impressed with the precision.) But over 42 years, that's an annual average of about \$8B per year, or something like 0.01 percent of GDP.
5. Stick to the climate science. Getting into mitigation options requires an even broader range of expertise

And, finally, here is a slide I used when talking to my climate class about climate coverage in the media. Good things to avoid in NCA6 [Judy, note reference to your blog •]

Koonin's red flags/checkpoints in climate coverage

- **Sloppy nomenclature that confuses the non-scientist**
 - "climate change" [scientific]: a change due to natural and/or human causes
 - "Climate Change" [UN and popular]: a change due only to human causes
- **Use of terms like "denier" or "alarmist"**
- **"97 percent of scientists agree ..."**
- **Weasel words**
 - "Might", "Could possibly...", "... as much as ...",
 - "... are projected to ...", "... cannot be ruled out"
- **Extreme scenarios framed as Business As Usual**
- **Omission of context**
 - No mention of uncertainty range or statistical significance
 - Failure to set a scale for very large or small numbers
 - No mention of historical comparisons (1-2 yrs = weather; >10 yrs = climate)
- **Inconsistency among different sources of coverage**
 - NYT vs WSJ vs FT vs ...
 - The original paper and/or its journal summary thereof (look at the data!)
 - The blogs
 - Consensus: <http://www.realclimate.org/>; <https://www.skepticalscience.com/>
 - Skeptical: <https://wattsupwiththat.com/>; <https://judithcurry.com/>

Steve Koonin

From: Judith Curry [curry.judith@gmail.com]
Sent: 8/13/2025 2:56:26 PM
To: Ross McKittrick [ross.mckittrick@gmail.com]
CC: John Christy [climateman60@gmail.com]; Steve Koonin [steven.koonin@gmail.com]; Jeremy T. Ison [jeremy.ison@hq.doe.gov]; Roy W. Spencer [roywspencer@hotmail.com]
Subject: Re: Tim Palmer

FYI Tim only considers the climate model estimates of ECS. Note: Nic Lewis' new ECS paper has been accepted, he is preparing a blog post for judithcurry.com

On Wed, Aug 13, 2025 at 6:52 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
Yes, that's quite good. I hope that in his review comments he explains where the $\text{Pr}(\text{ECS} > 4\text{C}) = 40\%$ view comes from. I assume it's from looking at the CMIP6 distribution, and that he puts more weight on the models than the data-driven approaches.

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Others?

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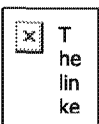
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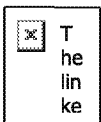
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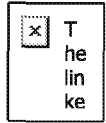


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From: Ison, Jeremy T. <jeremy.ison@hq.doe.gov>
Sent: Wednesday, August 13, 2025 9:57 AM
To: Judith Curry; John Christy
Cc: Ross McKittrick; Steve Koonin; Roy W. Spencer
Subject: RE: [EXTERNAL] Tim Palmer

Thank you.

From: Judith Curry <curry.judith@gmail.com>
Sent: Wednesday, August 13, 2025 9:25 AM
To: John Christy <climateman60@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>; Steve Koonin <steven.koonin@gmail.com>; Ison, Jeremy T. <jeremy.ison@hq.doe.gov>; Roy W. Spencer <roywspencer@hotmail.com>
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Use caution if this message contains attachments, links or requests for information.

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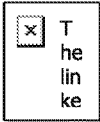


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Subject: curry bio sketch
Attachments: curry biosketch.docx

Attached is a beefed up version of my biosketch (previous one was relatively skimpy)

--



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Judith Curry, Ph.D. is Professor Emerita at the Georgia Institute of Technology, where she served as Chair of Earth and Atmospheric Sciences for 13 years. She is President and co-founder of Climate Forecast Applications Network (CFAN). Curry has a PhD in Geophysical Sciences from the University of Chicago. She has authored or coauthored 192 peer-reviewed papers in atmospheric and climate sciences, two textbooks, and most recently the book *Climate Uncertainty and Risk*. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, American Geophysical Union, and a Member of the American Academy of Sciences and Letters. She has served on several Science Steering Committees of the World Climate Research Program and also the DOE Biological & Environmental Research Advisory Committee, Earth Science Subcommittee of the NASA Advisory Council, and the NRC Space Studies Board and Climate Research Committee. Dr. Curry has given testimony in 13 Congressional Hearings.

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Tuesday, June 24, 2025 8:00 AM
To: Ross McKittrick; John Christy; Judith Curry; Roy Spencer; Travis Fisher; Josh Loucks; Seth Cohen
Subject: Fwd: OSTP Issues Agency Guidance for Gold Standard Science – The White House | June 23, 2025

>
> <https://www.whitehouse.gov/articles/2025/06/ostp-issues-agency-guidance-for-gold-standard-science/>
>
> (The seven page letter from OSTP Director Michael Kratsios to the heads of federal departments and agencies providing guidance for Gold Standard Science is hotlinked at the bottom of the one page announcement above.)

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6	47 chapter summary	
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8	86 all	

Comment or Suggested Edit

In general, criticism and re-analysis of past research is always welcome. This report summarizes some substantial concerns from a small group of researchers. The report should be reframed to reflect this and I provide some suggestions in a later comment. I suspect that simply publishing this report will not offset the hundreds of reports and publications on CO2 and Climate that have come before it. But, new analyses and communication within and outside the research community could make a positive difference, should the findings in this report be substantiated. The DOE Office of Science BER could be provided an opportunity to address the research uncertainties in this document in a thorough and robust manner.

As someone who used to read the DOE reports on CO2 as a graduate student in the 1990s and then conducted numerous analyses of carbon on many topic areas which were later confirmed by numerous other analyses, it seems somewhat cavalier for DOE to issue one brief conclusive report on the "impacts of carbon dioxide emissions". I suggest the following option: Change the title to "Topics of Uncertainty on the Impacts of Carbon Dioxide Emissions on the U.S. Climate" or "**An Assessment of CO2 Impacts on Climate to Guide Future Research**", and then use this report to drive research/analyses for each report chapter which would conclude in separate topical reports that could be finished within a year or two. In doing so, the DOE would positively contribute to addressing some of these standing issues and hopefully enable the nation to move forward in a more productive manner.

I appreciate the perspective. It could be useful to add or edit the Secretary's Forward to indicate that "**the report has been purposefully commissioned to researchers with alternative perspectives in an effort to address these perspectives and provide some closure for the American public, the US Economy, and US energy policy.**" I suggest this, because it will be very obvious that a handful of skeptics were chosen out of literally hundreds of extremely active and well-respected scientist. Addressing that upfront will immediately reduce criticism, and hopefully generate a positive environment to address these issues. Everyone would like to see convergence of findings on these issues.

Any increase in greening from additional CO2 will likely be more than offset by longer growing seasons with higher temperatures (i.e., more days over 100). This causes serious risk to the US midwestern "bread basket", which is why this has been considered a national security concern. The data supporting this trend has been published a few times now in Science by a fellow out of Stanford, among others. Sources: Lobell and Field. 2007, doi: 10.1088/1748-9326/2/1/014002; also Sloat et al. 2020, doi:10.1038/s41467-020-15076-4 has a thorough introduction with many citations.

My understanding is that the upper bound of emissions (i.e., very high) is business as usual, with no mitigation, and a high-end of growth. It's a worst, yet plausible, case scenario. Similarly, the lowest emissions (i.e., very low) scenario includes technologies that don't yet exist including significant CO2 removal. Both are there to understand plausible extremes. The more likely scenarios are the low to high scenarios. I'm sure researchers are open to revisiting how things are bounded and presented if there are reasonable objections. This may be true. But data driven analyses may not capture anticipated feedbacks.

I am a big fan of data and meta-analysis. However, I'll note that I do not think forest management practices are overlooked. In fact, it is one of the main driving story lines (i.e., too much fuelwood exists, so we need to harvest more forest). There remains strong debate on the efficacy of fuelwood removal over large areas as an effective means of wildfire reduction. The key to this analysis is to look at whether the extent (not the numbers) of fires has grown and whether the burned areas are returning to forests or returning to brush or grassland. If it's the latter, then that is more likely due to regional changes in climate (temp and precipitation).

I think we can point to sea-level rise in south florida, crop damage, and disease vectors fairly easily. I'm not aware of what costs are associated with these 3 items, but I suspect it's quite large.

Yes, this is an important paragraph. Most scientists are not activists. Just because there is a science finding, scientists don't expect that to turn into policy. The public and the democratic system can determine the policy using an evidence-based risk/benefit analysis, just as noted here. Opening up this conversation (which should have been done decades ago) would be welcome and would better engage the public on this issue. DOE could in fact take a leading role here and help address a major national issue.

This is all generally correct. I would like to think this is common knowledge.

Why use studies based on satellite sensors? I'm quite sure there are studies (again, out of Stanford) that use historic yield data (county-scale USDA data and global FAO data) with associated temperature and precipitation data. Those analyses do not agree with your findings here, I think. But, we can certainly pose these questions to our scientists that study and develop land models and develop a report based on all available data. I'll also note that for sometime data synthesis wasn't considered fundamental science and was therefore largely ignored. Enabling the researchers to conduct robust data analyses on this and other topics would be largely welcomed. All data is interesting and useful for perspective and understanding. But isn't the main question whether we are driving up CO2 and temp at a rapid pace in the post-industrial era? This graph does not help answer that question.

Stating that increased aridity in drylands will not lead to decreased productivity seems a bit questionable. We can point to precipitation gradients from high to low precipitation that supports forests to grasslands to shrublands, respectively. Less water in general will mean less productivity; this can be seen in different forest compositions as well. The authors cite Zhang et al. (2014), but Zhang's main point is that the direct CO2 effect may be causing greening in drylands that offsets the decreased precipitation. This may be more specific to dryland vegetation, and Zhang et al. specifically state that this finding is relevant to north-east Brazil, Namibia, western Sahel, Horn of Africa, and central Asia.

I do not disagree with this observation of a decline effect, and I have seen it in some of the early biomass energy analyses that appeared in prominent journals and were then corrected over a few years. While it is unfortunate that some try to grab headlines with unsupported assumptions, it does seem that other researchers tend to provide counter arguments and analyses fairly quickly, indicating that the system does in fact work fairly well.

Yes, CO2 uptake by land processes have uncertainty associated with them. It's worth noting that DOE researchers (many of whom are retired now) were world-leading and making progress in this area, but nearly all work on CO2 uptake and emissions stopped 10-15 years ago due to political pressure and political concerns. The Carbon Dioxide Information and Analysis Center at ORNL, now cancelled, was a main contributor to the Global Carbon Project. Now the US is woefully behind and ceding expertise on this to the Europeans (as cited in this report). We are also ceding expertise on carbon monitoring via satellites to other countries. There's nothing necessarily wrong with this if this is where the US wants to go, but it's important to recognize that we have lost significant capacity due to policy changes over many years.

Some of the early work on this topic was done by researchers at Stanford. But there are plenty of other papers. Here's one that came up in a quick search: <https://www.pnas.org/doi/10.1073/pnas.0906865106> Contradicting a number of large meta-analyses on the topic of decreased yields with increased temperature is ok. That's what science is all about. But it's going to have to be done in a more robust way than a couple paragraphs here with one or two citations. This is very important. I have not dug into the data on extreme storm data (both numbers and intensity). Getting researchers together that disagree on a topic, analyze the data, and publish findings together can be very productive. DOE could sponsor a workshop and bring together a broad range of experts and find answers to extreme weather trends.

I conducted some analyses on wildfire years ago. I saw the bias in the university textbooks and in the wildfire working groups, who essentially went by textbook teachings. It was rare that people went back to the original data. The last time I checked the actual data (a good 10 years ago), I found that...you're correct...the number of fires had not changed much. What does seem to be changing is that the extent of fires has grown, and this is mostly attributable to hotter and drier conditions. I do not believe there is more fuel load now than there was before the US was settled. Arguing that harvesting will decrease fire is nonsensical; you have no idea where the lightning is going to strike and subsidizing the thinning of all forest in the western fire zone would be cost prohibitive. I think we need to stop using wildfire management as a justification for harvesting. If we want to harvest more, than do it, and stop using fuel load arguments (which is more of a concept than proven reality) as a reason to do it. The biggest issue here is encroachment of housing communities into the Wild-Urban Interface (WUI) and how we want to handle that with policies. Fire is really only bad if it's burning someone's house down. Otherwise, it's a natural progression in forest dynamics. Sources: Campbell et al. 2012. doi:10.1890/110057.; Schoennagel and Nelson. 2011. doi:10.1890/090199.

The NCA5 is cited here and elsewhere. However, the USGCRP website that hosts the NCA reports has been removed. Hence, there is no way to read and review the referenced findings. This DOE report is therefore arguing against something that no longer exists, and that may appear questionable.

Given the satellite observed ice sheet dynamics, I'm not sure that ice sheet retreat is that hypothetical. This is the first time I have seen all sea-level rise estimates discredited by an offset from land subsidence. This is certainly a global dynamic that we would want to capture and understand in Earth system models, and DOE can look into this further with analyses and experiments if necessary.

This and other chapters cite the IPCC AR6. The IPCC provides a global process to address the issues and uncertainties in this report. Perhaps this report can set a path for pivoting research and re-engaging in a useful manner.

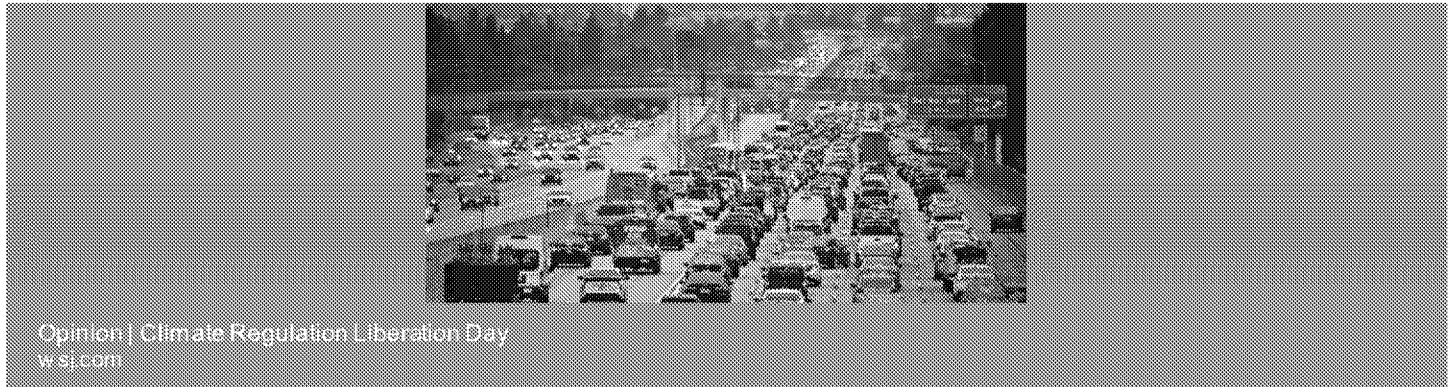
The last sentence in this summary is not necessarily accurate. The authors cite Ainsworth and Long (2020) with respect to increased CO2 effects on crops. But, Ainsworth and Long (2020) indicate that increased temp and decreased precipitation will have negative impacts on crops, while increased CO2 may offset some of those negative effects. It is the impact of CO2 on climate and the subsequent impact on crops that is the concern; not the direct effect of CO2 on crops.

Sent: Friday, July 25, 2025 4:51 PM
To: Ross McKittrick; John Christy
Cc: Roy Spencer; Steven Koonin; Judith Curry; Loucks, Joshua; Cohen, Seth
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Sent: Monday, July 28, 2025 8:52 AM
To: Roy Spencer; Ross McKittrick; John Christy
Cc: Steven Koonin; Judith Curry; Loucks, Joshua; Cohen, Seth
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

From: Steven Koonin [steven.koonin@gmail.com]
Sent: 7/29/2025 11:22:44 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Fisher, Travis [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=c6dbc4502be74ce6bda39baea264291e-7cf62492-3f]; curry.judith@gmail.com; ross.mckitrick@gmail.com; climatemanager60@gmail.com; roywspencer@hotmail.com; Cohen, Seth [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=24418dce056c4febf25028d929fb67ea-fb857aee-06]; Loucks, Joshua [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=2d080d4742984705ae930fad396649d5-1c03069d-41]
Subject: [EXTERNAL] Re: Audio of s1 remarks

Yes, the EB did do better.

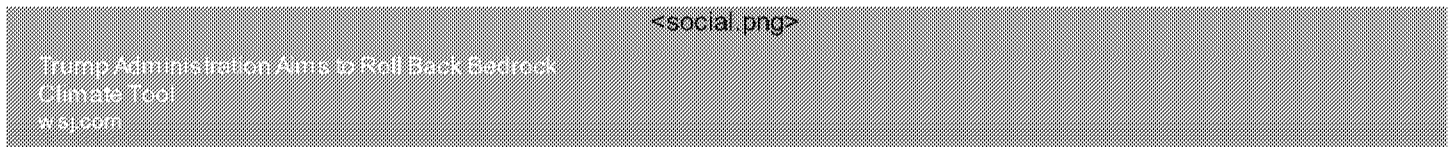


I wonder what the WSJ internal dynamics are like with this kind of disconnect between news and editorial.

Steven Koonin

On Jul 29, 2025, at 16:02, Steven Koonin <steven.koonin@gmail.com> wrote:

Disappointing WSJ news coverage



Expect the Editorial Board will do better.

Steven E. Koonin

On Jul 29, 2025, at 13:37, Fisher, Travis <travis.fisher@hq.doe.gov> wrote:

The landing page just went live on the DOE website: [Climate | Department of Energy](#)

From: Fisher, Travis
Sent: Tuesday, July 29, 2025 1:52 PM
To: steven.koonin@gmail.com; curry.judith@gmail.com; ross.mckitrick@gmail.com; climatemanager60@gmail.com; roywspencer@hotmail.com

Cc: Cohen, Seth <seth.cohen@hq.doe.gov>; Loucks, Joshua <joshua.loucks@hq.doe.gov>

Subject: FW: Audio of s1 remarks

We have audio of the Secretary's remarks from a few minutes ago. Kudos to you all for saying yes to Chris Wright when he called!

We expect the landing page to go live around 3pm ET, and it should be www.energy.gov/topics/climate. It will feature a press release, the CWG report itself, and the notice we are sending to the Federal Register today.

From: Woods, Andrea <andrea.woods@hq.doe.gov>

Sent: Tuesday, July 29, 2025 1:38 PM

To: Dankert, Charlie <charlie.dankert@hq.doe.gov>; Fisher, Travis <travis.fisher@hq.doe.gov>

Cc: Barrios, Audrey <audrey.barrios@hq.doe.gov>

Subject: FW: Audio of s1 remarks

Flagging this for both of you too! Really strong remarks from S1 at the event today. And a big shoutout to the excellent work of the Climate Working Group!

From: Dietderich, Ben <ben.dietderich@hq.doe.gov>

Date: Tuesday, July 29, 2025 at 1:26 PM

To: DL-PAPress <DL-PAPress@hq.doe.gov>, DL-PA-DIGITAL <DL-PA-DIGITAL@hq.doe.gov>, Barrios, Audrey <audrey.barrios@hq.doe.gov>

Subject: Audio of s1 remarks

Audio of s1 remarks attached! End is best part, Caroline can we transcribe asap?

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From: Judith Curry <curry.judith@gmail.com>
Sent: Monday, July 21, 2025 1:48 PM
To: Fisher, Travis
Cc: ross.mckitrick@gmail.com; roywspencer@hotmail.com; climateman60@gmail.com; steven.koonin@gmail.com; Cohen, Seth; Loucks, Joshua
Subject: [EXTERNAL] Re: FW: Update: Technical reviewers

Well this is more along the lines that I expected the reviews to take.

The main comment of substance here relates to the title, i agree with the reviewer here, we should rethink the title. Apart from the title, i don't see much here that would motivate edits/changes

On Mon, Jul 21, 2025 at 10:35 AM Fisher, Travis <travis.fisher@hq.doe.gov> wrote:

Another round of comments from the Office of Science. It's not clear to me whether [REDACTED] will offer a separate review, but her comments would be the last from the Office of Science.

We only have one of six reviews back from the national labs so far, so brace yourselves for potentially five additional sets of detailed comments.

No other program offices (like public affairs, congressional affairs, etc.) have submitted comments, and I don't expect them to.

I'll keep passing these along as I get them.

From: [REDACTED]
Sent: Monday, July 21, 2025 1:21 PM
To: Fisher, Travis <travis.fisher@hq.doe.gov>; [REDACTED]
Subject: RE: Update: Technical reviewers

[REDACTED]

Redacted

Redacted

Redacted

Redacted

Redacted

Redacted

Redacted

From: Steven Koonin [steven.koonin@gmail.com]
Sent: 7/24/2025 1:02:52 PM
To: Fisher, Travis [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=c6dbc4502be74ce6bda39baea264291e-7cf62492-3f]; 'Judith Curry' [curry.judith@gmail.com]; 'Ross McKittrick' [ross.mckittrick@gmail.com]
CC: Loucks, Joshua [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=2d080d4742984705ae930fad396649d5-1c03069d-41]; Cohen, Seth [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=24418dce056c4fe7b25028d929fb67ea-fb857aee-06]; 'John Christy' [climateman60@gmail.com]; 'Roy W. Spencer' [roywspencer@hotmail.com]
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)
Attachments: CWG Press Release SEK.docx

It's very good. Minor suggested edits in the attached - SEK

From: Fisher, Travis <travis.fisher@hq.doe.gov>
Sent: Wednesday, July 23, 2025 9:28 PM
To: Steven Koonin <steven.koonin@gmail.com>; 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

It's a heck of a report. I can't wait to see where we go from here!

Here's my first attempt at a press release—please make any edits or suggestions you like.

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Wednesday, July 23, 2025 5:50 PM
To: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>
Subject: [EXTERNAL] RE: July 23rd version - final (?)

Second that! Amazing effort, Ross.

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Wednesday, July 23, 2025 5:49 PM
To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Steven Koonin <steven.koonin@gmail.com>
Subject: Re: July 23rd version - final (?)

congrats to us all, and special thanks to RM for pulling it all together

On Wed, Jul 23, 2025 at 2:19 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Attached in MSWord and PDF formats.

All of Steve's corrections incorporated, also John's stray L and everything else I'm aware of.

The only remaining correction I have not been able to make is using a high-res version of the DoE logo. If that becomes the main focus of public criticism I will say we did well.

Ross

--



Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

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Department of Energy Releases Report from Distinguished Climate Working Group

The Department of Energy's Climate Working Group report highlights key differences between the scientific literature and the conventional narrative on climate change

Energy.gov

July 29, 2025

The Department of Energy's Climate Working Group report highlights key differences between the peer-reviewed academic literature and the conventional narrative on climate change

WASHINGTON—The U.S. Department of Energy (DOE) today released its report “A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate,” authored by five renowned climate experts assembled by Secretary of Energy Chris Wright.

From Secretary Wright's foreword:

“The rise of human flourishing over the past two centuries is a story worth celebrating. Yet we are told—relentlessly—that the very energy systems that enabled this progress now pose an existential threat. Hydrocarbon-based fuels, the argument goes, must be rapidly abandoned or else we risk planetary ruin. That view demands scrutiny. That's why I commissioned this report: to encourage a more thoughtful and science-based conversation about climate change and energy.”

The report, based upon the peer-reviewed scientific literature and government sources of data:

- Reviews scientific certainties and uncertainties in how anthropogenic emissions of carbon dioxide (CO₂) and other greenhouse gases have affected, or will affect, the Nation's climate, extreme weather events, and metrics of societal well-being.
- Assesses the near-term impacts of elevated concentrations of CO₂, including enhanced plant growth and reduced ocean alkalinity.
- Evaluates data and projections regarding long-term impacts of elevated concentrations of CO₂, including estimates of future warming.
- Finds that claims of increased frequency or intensity of hurricanes, tornadoes, floods, and droughts are not supported by U.S. historical data.
- Asserts that CO₂-induced warming might be less damaging economically than commonly believed, and that aggressive mitigation policies could prove more detrimental than beneficial.

The DOE report is intended to add clarity and balance to the debate over climate policy in the United States and abroad. In the spirit of open public discourse, a notice of availability and public comment will be published in the Federal Register—all interested parties are encouraged to submit comments.

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Thursday, July 24, 2025 4:14 PM
To: 'John Christy'; 'Ross McKittrick'
Cc: 'Roy Spencer'; Fisher, Travis; 'Judith Curry'; Loucks, Joshua; Cohen, Seth
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Got a similar call from Scott Waldmann, but let it go to voicemail.

He said he wanted to speak on background about the endangerment finding and “some of the climate work” I’ve been doing.

I’ve not returned his call.

From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 24, 2025 3:13 PM
To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Fisher, Travis <travis.fisher@hq.doe.gov>; Judith Curry <curry.judith@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>
Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

Just got a call from Scott at Politico stating he knows I've worked on a DoE science report. I said no comment. (He uses his wife's cell phone, so you don't know it's him when you pick up.)

John C.

On Thu, Jul 24, 2025 at 10:24 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

PS here are the report files now with a hi-res logo included.

On Thu, Jul 24, 2025 at 10:18 AM Steven Koonin <steven.koonin@gmail.com> wrote:

If you want to shorten Ross’ proposed title a bit, it could read:

Department of Energy Releases Report That Challenges Common Misconceptions About Climate Change

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Thursday, July 24, 2025 11:16 AM
To: John Christy <climateman60@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Fisher, Travis

<travis.fisher@hq.doe.gov>; Judith Curry <curry.judith@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>;
Cohen, Seth <seth.cohen@hq.doe.gov>

Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

The title might need to say a bit more, e.g.

Department of Energy Releases Report of Climate Working Group That Challenges Common Misconceptions
About Climate Change

and then the remainder follows the text as shown in Steve's edit, with "renowned" replaced by "eminent",
there being no adjective that won't draw scorn from the haters, but we might as well pick the word we like
best.

On Thu, Jul 24, 2025 at 9:09 AM John Christy <climateman60@gmail.com> wrote:

Looks good.

John C.

On Thu, Jul 24, 2025 at 8:59 AM Steven Koonin <steven.koonin@gmail.com> wrote:

And with me.

SEK

From: Roy Spencer <roywspencer@hotmail.com>

Sent: Thursday, July 24, 2025 9:49 AM

To: Fisher, Travis <travis.fisher@hq.doe.gov>; Steven Koonin <steven.koonin@gmail.com>; 'John Christy' <climateman60@gmail.com>
Cc: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckitrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Fine with me.

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: "Fisher, Travis" <travis.fisher@hq.doe.gov>

Date: 7/24/25 8:42 AM (GMT-06:00)

To: Steven Koonin <steven.koonin@gmail.com>, 'John Christy' <climateman60@gmail.com>

Cc: 'Judith Curry' <curry.judith@gmail.com>, 'Ross McKittrick' <ross.mckitrick@gmail.com>, "Loucks, Joshua" <Joshua.Loucks@hq.doe.gov>, "Cohen, Seth" <seth.cohen@hq.doe.gov>, "'Roy W. Spencer'" <roywspencer@hotmail.com>

Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Ok I'm going with eminent for now. All of this is subject to review by the office of public affairs, so we'll see what sticks.

In this next iteration I added your bios at the end (straight copy/paste from the report). Are you all comfortable if we decide to take that approach?

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Thursday, July 24, 2025 9:21 AM
To: Fisher, Travis <travis.fisher@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>
Cc: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'Roy W. Spencer' <roywspencer@hotmail.com>
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Perhaps “eminent” .

Although in some eyes, “notorious” would be appropriate.

From: Fisher, Travis <travis.fisher@hq.doe.gov>
Sent: Thursday, July 24, 2025 9:07 AM
To: John Christy <climateman60@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; Roy W. Spencer <roywspencer@hotmail.com>
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

I don’t want anyone to think of you all as circus performers! I was looking for a synonym for “distinguished,” with the bonus of being well-known. I’m open to ideas: [RENOWNED Synonyms: 104 Similar and Opposite Words | Merriam-Webster Thesaurus](#)

From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 24, 2025 8:53 AM
To: Fisher, Travis <travis.fisher@hq.doe.gov>
Cc: Steven Koonin <steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; Roy W. Spencer <roywspencer@hotmail.com>
Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

Travis

“Renowned” sounds a little like a circus performer.

I wonder how many reporters will actually read the whole document? I suspect one of our common answers to their questions is, "just read the report!"

John C.

Sent from my iPhone

On Jul 23, 2025, at 8:28 PM, Fisher, Travis <travis.fisher@hq.doe.gov> wrote:

It's a heck of a report. I can't wait to see where we go from here!

Here's my first attempt at a press release—please make any edits or suggestions you like.

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Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>
Subject: [EXTERNAL] RE: July 23rd version - final (?)

Second that! Amazing effort, Ross.

SEK

From: Judith Curry <curry.judith@gmail.com>
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To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; John Christy <climateman60@gmail.com>; Roy W. Spencer

<roywspencer@hotmail.com>; Steven Koonin <steven.koonin@gmail.com>

Subject: Re: July 23rd version - final (?)

congrats to us all, and special thanks to RM for pulling it all together

On Wed, Jul 23, 2025 at 2:19 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

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The only remaining correction I have not been able to make is using a high-res version of the DoE logo. If that becomes the main focus of public criticism I will say we did well.

Ross

--

<image001.jpg>

Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

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<CWG Press Release.docx>

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Friday, July 25, 2025 8:37 PM
To: Fisher, Travis; Ross McKitrick; John Christy
Cc: Steven Koonin; Judith Curry; Loucks, Joshua; Cohen, Seth
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

That's fine.

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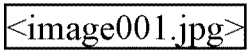
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Ross

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<http://www.cfanclimate.net>

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<CWG Press Release.docx>

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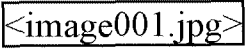
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Attached in MSWord and PDF formats.

All of Steve's corrections incorporated, also John's stray L and everything else I'm aware of.

The only remaining correction I have not been able to make is using a high-res version of the DoE logo. If that becomes the main focus of public criticism I will say we did well.

Ross

--

<image001.jpg>

Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

This message does not originate from a known Department of Energy email system.
Use caution if this message contains attachments, links or requests for information.

<CWG Press Release.docx>

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To: Steven Koonin
Cc: Fisher, Travis; John Christy; Roy Spencer; Judith Curry; Loucks, Joshua; Cohen, Seth
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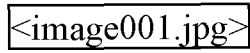
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<http://www.cfanclimate.net>

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Use caution if this message contains attachments, links or requests for
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<CWG Press Release.docx>

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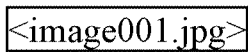
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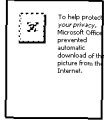
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Ross

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<image001.jpg>

Judith Curry, President
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<http://www.cfanclimate.net>

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<CWG Press Release.docx>

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To: Ross McKittrick
Cc: Steven Koonin; Fisher, Travis; Roy Spencer; Judith Curry; Loucks, Joshua; Cohen, Seth
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It's fine.

John C.

On Fri, Jul 25, 2025 at 4:05 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
I'm fine with that.

On Fri, Jul 25, 2025 at 3:56 PM Steven Koonin <steven.koonin@gmail.com> wrote:

I'm OK with that change.

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Hi all,

I have a request for a minor change in the preface. The last line presently reads: "We are also grateful to a team of anonymous peer reviewers whose input helped improve the final report."

Would it cause any heartburn to change the line to read "We are also grateful to a team of anonymous **DOE and national lab** reviewers whose input helped improve the final report."?

Best,

Travis

PS – the Secretary is reading the updated version tonight.

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Didn't even think of that. If it comes up I guess I'd invoke McShane and Weiner and say the ipcc has never addressed the problem that the millennial scale back-projections at the hemispheric scale are simply too noisy to draw precise conclusions. And nothing core to our report depended one way or the other on those issues.

On Thu, Jul 24, 2025 at 5:59 PM John Christy <climateman60@gmail.com> wrote:

Ross

What will you say when asked why we didn't deal with all the Hockey Sticks from Mann to IPCC AR6?

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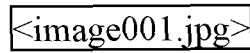
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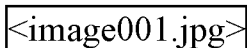
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CFAN - Climate Forecast Applications Network
Reno, NV USA

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<CWG Press Release.docx>

From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 24, 2025 3:13 PM
To: Ross McKittrick
Cc: Steven Koonin; Roy Spencer; Fisher, Travis; Judith Curry; Loucks, Joshua; Cohen, Seth
Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

Just got a call from Scott at Politico stating he knows I've worked on a DoE science report. I said no comment. (He uses his wife's cell phone, so you don't know it's him when you pick up.)

John C.

On Thu, Jul 24, 2025 at 10:24 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
PS here are the report files now with a hi-res logo included.

On Thu, Jul 24, 2025 at 10:18 AM Steven Koonin <steven.koonin@gmail.com> wrote:

If you want to shorten Ross' proposed title a bit, it could read:

Department of Energy Releases Report That Challenges Common Misconceptions About Climate Change

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Thursday, July 24, 2025 11:16 AM
To: John Christy <climateman60@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Fisher, Travis <travis.fisher@hq.doe.gov>; Judith Curry <curry.judith@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>
Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

The title might need to say a bit more, e.g.

Department of Energy Releases Report of Climate Working Group That Challenges Common Misconceptions About Climate Change

and then the remainder follows the text as shown in Steve's edit, with "renowned" replaced by "eminent", there being no adjective that won't draw scorn from the haters, but we might as well pick the word we like best.

On Thu, Jul 24, 2025 at 9:09 AM John Christy <climateman60@gmail.com> wrote:

Looks good.

John C.

On Thu, Jul 24, 2025 at 8:59 AM Steven Koonin <steven.koonin@gmail.com> wrote:

And with me.

SEK

From: Roy Spencer <roywspencer@hotmail.com>

Sent: Thursday, July 24, 2025 9:49 AM

To: Fisher, Travis <travis.fisher@hq.doe.gov>; Steven Koonin <steven.koonin@gmail.com>; 'John Christy' <climateman60@gmail.com>

Cc: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>

Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Fine with me.

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: "Fisher, Travis" <travis.fisher@hq.doe.gov>

Date: 7/24/25 8:42 AM (GMT-06:00)

To: Steven Koonin <steven.koonin@gmail.com>, 'John Christy' <climateman60@gmail.com>

Cc: 'Judith Curry' <curry.judith@gmail.com>, 'Ross McKittrick' <ross.mckittrick@gmail.com>, "Loucks, Joshua" <Joshua.Loucks@hq.doe.gov>, "Cohen, Seth" <seth.cohen@hq.doe.gov>, "Roy W. Spencer" <roywspencer@hotmail.com>

Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Ok I'm going with eminent for now. All of this is subject to review by the office of public affairs, so we'll see what sticks.

In this next iteration I added your bios at the end (straight copy/paste from the report). Are you all comfortable if we decide to take that approach?

From: Steven Koonin <steven.koonin@gmail.com>

Sent: Thursday, July 24, 2025 9:21 AM

To: Fisher, Travis <travis.fisher@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>

Cc: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'Roy W. Spencer' <roywspencer@hotmail.com>

Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

Perhaps "eminent".

Although in some eyes, "notorious" would be appropriate.

From: Fisher, Travis <travis.fisher@hq.doe.gov>
Sent: Thursday, July 24, 2025 9:07 AM
To: John Christy <climateman60@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; Roy W. Spencer <roywspencer@hotmail.com>
Subject: RE: [EXTERNAL] RE: July 23rd version - final (?)

I don't want anyone to think of you all as circus performers! I was looking for a synonym for "distinguished," with the bonus of being well-known. I'm open to ideas: [RENOWNED Synonyms: 104 Similar and Opposite Words | Merriam-Webster Thesaurus](#)

From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 24, 2025 8:53 AM
To: Fisher, Travis <travis.fisher@hq.doe.gov>
Cc: Steven Koonin <steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; Roy W. Spencer <roywspencer@hotmail.com>
Subject: Re: [EXTERNAL] RE: July 23rd version - final (?)

Travis

"Renowned" sounds a little like a circus performer.

I wonder how many reporters will actually read the whole document? I suspect one of our common answers to their questions is, "just read the report!"

John C.

Sent from my iPhone

On Jul 23, 2025, at 8:28 PM, Fisher, Travis <travis.fisher@hq.doe.gov> wrote:

It's a heck of a report. I can't wait to see where we go from here!

Here's my first attempt at a press release—please make any edits or suggestions you like.

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Wednesday, July 23, 2025 5:50 PM
To: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; 'John Christy' <climateman60@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>
Subject: [EXTERNAL] RE: July 23rd version - final (?)

Second that! Amazing effort, Ross.

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Wednesday, July 23, 2025 5:49 PM
To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Fisher, Travis <travis.fisher@hq.doe.gov>; Loucks, Joshua <Joshua.Loucks@hq.doe.gov>; Cohen, Seth <seth.cohen@hq.doe.gov>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Steven Koonin <steven.koonin@gmail.com>
Subject: Re: July 23rd version - final (?)

congrats to us all, and special thanks to RM for pulling it all together

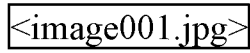
On Wed, Jul 23, 2025 at 2:19 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Attached in MSWord and PDF formats.

All of Steve's corrections incorporated, also John's stray L and everything else I'm aware of.

The only remaining correction I have not been able to make is using a high-res version of the DoE logo. If that becomes the main focus of public criticism I will say we did well.

Ross



Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

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<CWG Press Release.docx>

From: Ross McKittrick [ross.mckittrick@gmail.com]
Sent: 7/23/2025 3:51:05 PM
To: Judith Curry [curry.judith@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; John Christy [climateman60@gmail.com]; Steven Koonin [steven.koonin@gmail.com]; Fisher, Travis [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=c6dbc4502be74ce6bda39baea264291e-7cf62492-3f]; Cohen, Seth [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=24418dce056c4fefb25028d929fb67ea-fb857aee-06]; Loucks, Joshua [/o=ExchangeLabs/ou=Exchange Administrative Group (FYDIBOHF23SPDLT)/cn=Recipients/cn=2d080d4742984705ae930fad396649d5-1c03069d-41]
Subject: [EXTERNAL] July 23 edition
Attachments: DoE.Report.July23.docx

Hi everyone

This is the current July 23 edition. It incorporates the Section numbers from Steve in the Executive Summary, the fixes noted this AM by John and Judy in response to review comments and the various edits sent today by Steve (deleting reference to deleted Fig 2.2, sentence in Preface about draft deadline, various comments and 'that's').

Still needed: hi-res logo.

I have to go out for a few hours. My suggestion is that everyone triple check the changes that ought to be in there and if any are missing please write them down in an email rather than marking this draft up. Steve, keep going through the July 22 doc. For the sake of minimizing the need for last minute tinkering only note edits that are absolutely essential. We can live with stylistic deficiencies e.g. the occasional missing comma.

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A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate

Climate Working Group
United States Department of Energy
July 22, 2025

A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate

Report to U.S. Energy Secretary Christopher Wright
July 22, 2025

Climate Working Group:

John Christy, Ph.D.

Judith Curry, Ph.D.

Steven Koonin, Ph.D.

Ross McKittrick, Ph.D.

Roy Spencer, Ph.D.

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Suggested citation:

Climate Working Group (2025) A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate. Washington DC: Department of Energy, July 22, 2025

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Table of Contents

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SECRETARY'S FOREWORD

Energy, Integrity, and the Power of Human Potential

Over my lifetime, I've had the privilege of working as an energy entrepreneur across a range of fields—nuclear, geothermal, natural gas, and more—and I now serve as Secretary of Energy under President Donald Trump. But above all, I'm a physical scientist who sees modern energy as nothing short of miraculous. It powers every aspect of modern life, drives every industry, and has made America an energy powerhouse with the ability to fuel global progress.

The rise of human flourishing over the past two centuries is a story worth celebrating. Yet we are told—relentlessly—that the very energy systems that enabled this progress now pose an existential threat. Hydrocarbon-based fuels, the argument goes, must be rapidly abandoned or else we risk planetary ruin.

That view demands scrutiny. That's why I commissioned this report: to encourage a more thoughtful and science-based conversation about climate change and energy. With my technical background, I've reviewed reports from the Intergovernmental Panel on Climate Change, the U.S. government's assessments, and the academic literature. I've also engaged with many climate scientists, including the authors of this report.

What I've found is that media coverage often distorts the science. Many people—even well-meaning ones—walk away with a view of climate change that is exaggerated or incomplete. To provide clarity, I asked a diverse team of independent experts to summarize the current state of climate science, with a focus on how it relates to the United States.

I didn't select these authors because we always agree—far from it. In fact, they may not always agree with each other. But I chose them for their rigor, honesty, and willingness to elevate the debate. I exerted no control over their conclusions. What you'll read are their words, drawn from the best available data and scientific assessments.

I've reviewed the report carefully and challenged its findings. I believe it faithfully represents the state of climate science today. Still, many readers may be surprised by its conclusions—which differ in important ways from the mainstream narrative. That's a sign of how far the public conversation has drifted from the science itself.

To correct course, we need open, respectful, and informed debate. That's why I'm inviting public comment on this report. Honest scrutiny and scientific transparency should be at the heart of our policymaking.

Climate change is real, and it deserves attention. But it is not the greatest threat facing humanity. That distinction belongs to global energy poverty. As someone who values data, I know that improving the human condition depends on expanding access to reliable, affordable energy. Climate change is a challenge—not a catastrophe. But misguided policies based on fear rather than facts could truly endanger human well-being.

We stand at the threshold of a new era of energy leadership. If we empower innovation rather than restrain it, America can lead the world in providing cleaner, more abundant energy—lifting billions out of poverty, strengthening our economy, and improving our environment along the way.

EXECUTIVE SUMMARY

This report reviews scientific certainties and uncertainties in how anthropogenic carbon dioxide (CO₂) and other greenhouse gas emissions have affected, or will affect, the Nation's climate, extreme weather events, and selected metrics of societal well-being. Those emissions are increasing the concentration of CO₂ in the atmosphere through a complex and variable carbon cycle, where some portion of the additional CO₂ persists in the atmosphere for centuries.

Elevated concentrations of CO₂ directly enhance plant growth, globally contributing to “greening” the planet and increasing agricultural productivity [Section 2.1, Chapter 9]. They also make the oceans less alkaline (lower the pH). That is possibly detrimental to coral reefs, although the recent rebound of the Great Barrier Reef suggests otherwise [Section 2.2].

Carbon dioxide also acts as a greenhouse gas, exerting a warming influence on climate and weather [Section 3.1]. Climate change projections require scenarios of future emissions. There is evidence that scenarios widely-used in the impacts literature have overstated observed and likely future emission trends [Section 3.1].

The world's several dozen global climate models offer little guidance on how much the climate responds to elevated CO₂, with the average surface warming under a doubling of the CO₂ concentration ranging from 1.8°C to 5.7°C [Section 4.2]. Data-driven methods yield a lower and narrower range [Section 4.3]. Global climate models generally run “hot” in their description of the climate of the past few decades – too much warming at the surface and too much amplification of warming in the lower- and mid-troposphere [Sections 5.2-5.4]. The combination of overly sensitive models and implausible extreme scenarios for future emissions yields exaggerated projections of future warming.

Most extreme weather events in the U.S. do not show long-term trends. Claims of increased frequency or intensity of hurricanes, tornadoes, floods, and droughts are not supported by U.S. historical data [Sections 6.1-6.7]. Additionally, forest management practices are often overlooked in assessing changes in wildfire activity [Section 6.8]. Global sea level has risen approximately 8 inches since 1900, but there are significant regional variations driven primarily by local land subsidence; U.S. tide gauge measurements in aggregate show no obvious acceleration in sea level rise beyond the historical average rate [Chapter 7].

Attribution of climate change or extreme weather events to human CO₂ emissions is challenged by natural climate variability, data limitations, and inherent model deficiencies [Chapter 8]. Moreover, solar activity's contribution to the late 20th century warming might be underestimated [Section 8.3.1].

Both models and experience suggest that CO₂-induced warming might be less damaging economically than commonly believed, and excessively aggressive mitigation policies could prove more detrimental than beneficial [Chapters 9, 10, Section 11.1]. Social Cost of Carbon estimates, which attempt to quantify the economic damage of CO₂ emissions, are highly sensitive to their underlying assumptions and so provide limited independent information [Section 11.2].

U.S. policy actions are expected to have undetectably small direct impacts on the global climate and any effects will emerge only with long delays [Chapter 12].

PREFACE

This document originated in late March 2025 when Secretary Wright assembled an independent group to write a report on issues in climate science relevant for energy policymaking, including evidence and perspectives that challenge the mainstream consensus. We agreed to undertake the work on the condition that there would be no editorial oversight by the Secretary, the Department of Energy, or any other government personnel. This condition has been honored throughout the process and the writing team has worked with full independence.

The group began working in early April with a May 28 deadline to deliver a draft for peer review. The short timeline and the technical nature of the material meant that we could not comprehensively review all topics. Rather, we chose to focus on topics that are treated by a serious, established academic literature; that are relevant to our charge; that are downplayed in, or absent from, recent assessment reports; and that are within our competence.

While the report is intended to be accessible to non-experts, we have omitted some introductory or explanatory material that can easily be accessed elsewhere. Nor have we attempted to survey the entire literature related to the topics covered. We have focused as much as possible on literature published since 2020 and referenced previous IPCC and NCA assessment reports. We have also used data through 2024 where possible.

The writing team is grateful to Secretary Wright for the opportunity to prepare this report and for his support of independent scientific assessment and open scientific debate. We are also grateful to a team of anonymous peer reviewers whose input helped improve the final report.

John Christy, Ph.D.

Judith Curry, Ph.D.

Steven Koonin, Ph.D.

Ross McKittrick, Ph.D.

Roy Spencer, Ph.D.

**PART I: DIRECT HUMAN INFLUENCE ON ECOSYSTEMS AND THE
CLIMATE**

1 CARBON DIOXIDE AS A POLLUTANT

Chapter summary:

Carbon dioxide (CO₂) differs in many ways from the so-called Criteria Air Pollutants. It does not affect local air quality and has no human toxicological implications at ambient levels. It is an issue of concern because of its effects on the global climate.

The Clean Air Act of 1970 defined six so-called Criteria Air Contaminants subject to regulation (EPA): particulate matter, ground-level ozone, sulfur dioxide, nitrogen dioxide, lead, and carbon monoxide. In 2007, the Supreme Court ruled that greenhouse gases (CO₂ among them) were also “pollutants” subject to regulation under Clean Air Act (*Mass. v. EPA*, 2007). While the definition of “pollutant” is ultimately a legal matter, there are important scientific distinctions between CO₂ and the Criteria Air Contaminants. The latter are subject to regulatory control because they cause local problems depending on concentrations that include nuisances (odor, visibility), damage to plants, and, at high enough exposure levels, toxicological effects in humans. In contrast, CO₂ is odorless, does not affect visibility and has no toxicological effects at ambient levels. It is a naturally occurring part of the atmosphere and a key component of human and plant respiration. CO₂ is essential for plant photosynthesis and higher levels are beneficial for vegetation. In these aspects, CO₂ is similar to water vapor.

Ambient outdoor air today contains about 430 parts per million (ppm) CO₂, increasing at about 2 ppm per year. The U.S. Occupational Safety and Health Administration issues guidelines for indoor workplaces in which elevated CO₂ might be encountered, such as where dry ice is used. The Permissible Exposure Limit is 5,000 ppm over 8 hours (OSHA, 2024). Allen *et al.* (2015) reported evidence of diminished performance on some cognitive tasks among workers in office cubicles when exposed to CO₂ levels above 1,000-1,500 ppm. These levels are far larger than any plausible ambient outdoor value through the end of the 22nd century.

The growing amount of CO₂ in the atmosphere directly influences the earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and by neutralizing ocean alkalinity. But the primary concern about CO₂ is its role as a greenhouse gas (GHG) that alters the earth’s energy balance, warming the planet. How the climate will respond to that influence is a complex question that will occupy much of this report.

References

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- Massachusetts v. Environmental Protection Agency, 549 U.S. 497 (2007). [[HYPERLINK "https://www.oyez.org/cases/2006/05-1120"](https://www.oyez.org/cases/2006/05-1120)]
- U.S. Environmental Protection Agency. (n.d.). Criteria air pollutants. [[HYPERLINK "https://www.epa.gov/criteria-air-pollutants"](https://www.epa.gov/criteria-air-pollutants)]
- U.S. Occupational Safety and Health Administration. (2024). OSHA occupational chemical database: Carbon dioxide. [[HYPERLINK "https://www.osha.gov/chemicaldata/183"](https://www.osha.gov/chemicaldata/183)]

2 DIRECT IMPACTS OF CO₂ ON THE ENVIRONMENT

Chapter summary:

CO₂ enhances photosynthesis and improves plant water use efficiency, thereby promoting plant growth. Global greening due in part to increased CO₂ levels in the atmosphere is well-established on all continents.

CO₂ absorption in sea water makes the oceans less alkaline. The recent decline in pH is within the range of natural variability on millennial time scales. Most ocean life evolved when the oceans were mildly acidic. Decreasing pH might adversely affect corals, although the Australian Great Barrier Reef has shown considerable growth in recent years.

2.1 CO₂ as a contributor to global greening

The growing CO₂ concentration in the atmosphere has the important positive effect of promoting plant growth by enhancing photosynthesis and improving water use efficiency. That is evident in the “global greening” phenomenon discussed below, as well as in the improving agricultural yields discussed in Chapter 10. Here we focus just on CO₂ fertilization; research on combined effects due to temperature and precipitation changes are discussed in Chapter 10.

2.1.1 Measurement of global greening

“Greening” refers to an increase in the fraction of the Earth’s surface covered by plants. It can be quantified by the “Leaf Area Index” (LAI) measured by satellite. Many studies over the past decade have confirmed a global greening pattern (increase in LAI) attributable in part to rising CO₂ levels. Zhu *et al.* (2016) was one of the first studies to report that global greening was detectable using satellite sensors. From 1982 to 2011 they detected greening over 25-50 percent of the Earth versus “browning” over only four percent and attributed 70 percent of the greening to rising CO₂ levels (see Figure 2.1). Other contributors included land-use changes, warming and nitrogen. The fraction attributable to CO₂ was largest in the tropics; other factors played more dominant roles in CONUS.

Zeng *et al.* (2017) confirmed the pattern of greening, noting that over thirty years it had added 8 percent to global leaf area and that greening was mitigating warming. Greening has been observed globally. Chen *et al.* (2019) show that in China and India much of it is driven by land management changes. Thus, while China accounts for only 6.6 percent of global vegetated area it accounts for 25 percent of global net increase in LAI. Piao *et al.* (2020) noted that greening was even observable in the Arctic. CO₂ fertilization effects are influenced by local temperature and nutrient and water availability, all of which vary regionally.

While plant models predict increased photosynthesis in response to rising CO₂, Haverd *et al.* (2020) reported a CO₂ fertilization rate much larger than model predictions. That is, CO₂ fertilization had driven an increase in observed global photosynthesis by 30 percent since 1900, versus 17 percent predicted by plant models. If true it would indicate that global models of the socioeconomic impacts of rising CO₂ have understated the benefits to crops and agriculture. Keenan *et al.* (2023), however, estimated a lower fertilization rate more in line with models. The connection between CO₂ fertilization and agriculture will be discussed in Chapter 9.

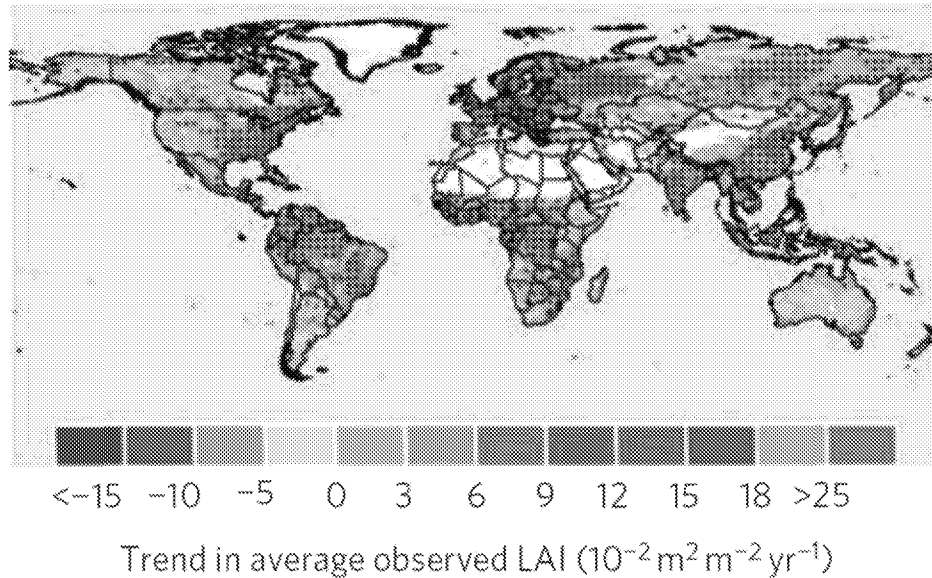


Figure 2.1: Trends in average Leaf Area Index (LAI). Source: Zhu *et al.* 2016 Figure 3.

Piao *et al.* (2020) and Chen *et al.* (2024) report that the greening trend continues with no evidence of slowdown, and CO₂ fertilization remains the dominant driver

2.1.2 Photosynthesis and CO₂ levels

Plants build biomass through *photosynthesis*, a process that converts carbon dioxide, water, and light into sugar. The plant enzyme responsible for photosynthesis is Ribulose-1,5-bisphosphate-carboxylase/oxygenase or “Rubisco”. Photosynthesis is initiated when CO₂ is available at the surface of the Rubisco enzyme where it is converted to a molecule with 3 carbon atoms and thereafter incorporated into plant mass. This is referred to as the “C3” process.

Rubisco is estimated to have evolved about 3 billion years ago. Over geological time the Earth’s atmospheric CO₂ levels were usually many times higher than they are today. About 400 million years ago CO₂ levels were an estimated 2,000-4,000 ppm and were at or above 1,000 ppm for much of the interval from 200 to 50 million years ago (Bernier 2006, Judd *et al.* 2024). Over the past 35 million years the level of atmospheric CO₂ has been steadily declining, falling to as low as 170 ppm during glaciations (Gerhart and Ward 2010). While the modern rate of change in CO₂ may be high compared to prior intervals, the geological evidence is that plants and animals evolved under much higher CO₂ levels than at present.

In response to low-CO₂ conditions some plants evolved another photosynthetic pathway called C4, in which CO₂ is concentrated in the vicinity of Rubisco, allowing for the C3 process to function more efficiently. For agricultural purposes the plant categories are:

- C3: rice, wheat, soybeans and most other crops
- C4: maize (corn), sugar cane, millet, sorghum

Had atmospheric CO₂ levels continued declining, plant growth would have declined and eventually ceased. Below 180 ppm, the growth rates of many C3 species are reduced 40-60 percent relative to 350 ppm (Gerhart and Ward 2010) and growth has stopped altogether under experimental conditions of 60—140 ppm CO₂. Some C4 plants are still able to grow at levels even as low as 10 ppm, albeit very slowly (Gerhart and Ward 2010).

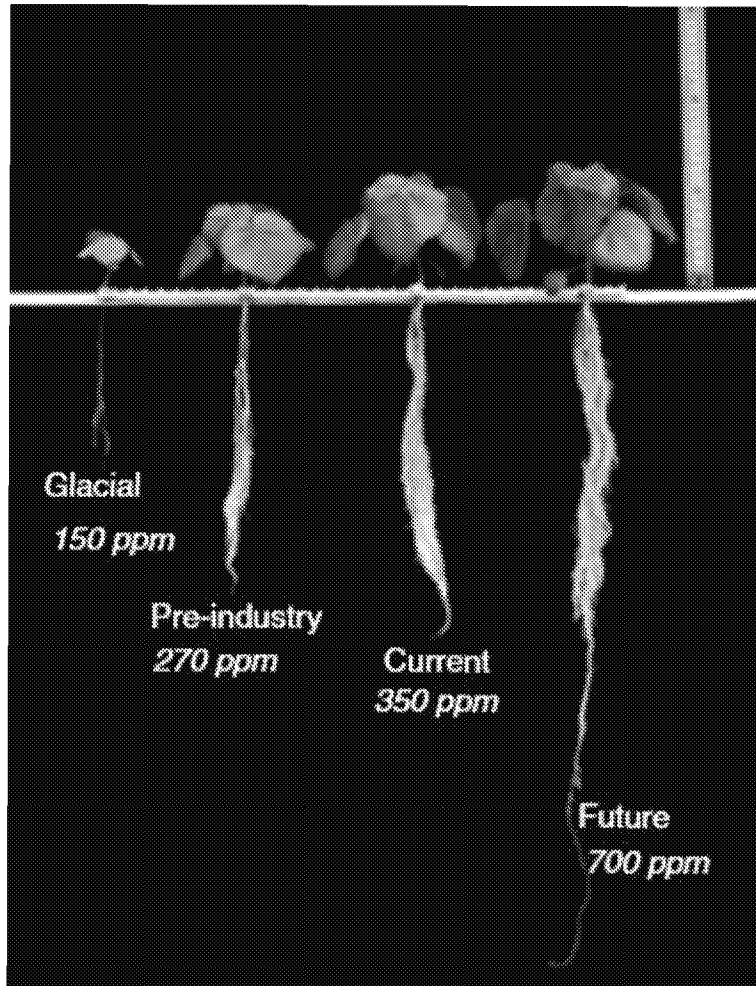


Figure 2.2: growth of *Abutilon theophrasti* after 14 days under identical conditions but for the indicated variations in CO₂ levels. Source: Gerhart and Ward (2010). Note “Current” corresponds to 1988 in image.

Current CO₂ levels are about 430 ppm, up from 280 ppm in the early 1800s. The positive response of plants to extra CO₂ is illustrated in Figure 2.2, reproduced from Gerhart and Ward (2010). It shows the growth effect of CO₂ on Velvetleaf (*Abutilon theophrasti*) seedlings over 14 days under controlled conditions where only the CO₂ exposure is varied. The gains induced by increasing CO₂ from 150 ppm to 350 ppm continue under a further doubling to 700 ppm.

Over the past 60+ years there have been thousands of studies on the response of plants to rising CO₂ levels. The overwhelming theme is that plants, especially C3 plants, benefit from extra CO₂. There are two mechanisms by which CO₂ confers a growth benefit:

- Enhanced photosynthesis via the metabolic pathways described above.
- Increased water use efficiency. This arises because plants draw in CO₂ by opening the stomata (pores) on the leaf surface. When CO₂ is scarce the stomata must be kept wide open for long periods, allowing water to evaporate. Under enriched CO₂ conditions the stomata remain closed for longer periods, thus helping the plant retain water longer, and so increasing water use efficiency.

Specific effects of climate change on U.S. agriculture will be reviewed in Chapter 9.

2.1.3 Rising CO₂ and crop water use efficiency

Deryng *et al.* (2016) surveyed evidence on crop water productivity (CWP), the yield per unit of water used, drawing attention to the potential for CO₂ both to enhance photosynthesis and to reduce leaf-level transpiration (water loss during leaf respiration). They surveyed all available FACE data (Free Air CO₂ Enrichment—see Chapter 9) on crop yield changes for maize (corn), wheat, rice, and soybean and combined it with crop model data simulating yield responses as of 2080 under the extreme RCP8.5 emissions scenario in four growing regions (Tropics, Arid, Temperate and Cold) each of which were split into rainfed and irrigated sub-regions. They reported that models without CO₂ fertilization predicted CWP losses in every region, but those were more than offset by CO₂ fertilization so that all regions showed a net CWP gain. Deryng *et al.* (2016) also reported that negative impacts of warming on wheat and soybean yields were fully offset by CWP gains and mitigated by up to 90 percent for rice and 60 percent for maize.

Similarly, Cheng *et al.* (2017) noted that increased Gross Primary Production from 1982 to 2011 due to rising CO₂ uptake was accompanied by such large gains in CWP that global water use by plants had not increased, despite the extra biomass.

Deryng *et al.* (2016) assumed that climate change would “exacerbate water scarcity”. Yet while models do predict that drylands will expand under climate warming, current data show the opposite: greening is happening even in arid areas. Zhang *et al.* (2024) report that due to increased CO₂ levels “increasing aridity in drylands won’t lead to a general loss of vegetation productivity”; at most only 4 percent of currently arid areas will see increased desertification.

2.1.4 CO₂ fertilization benefits in IPCC Reports

The IPCC has only minimally discussed global greening and CO₂ fertilization of agricultural crops. The topic is briefly acknowledged in a few places in the body of the IPCC 6th and earlier Assessment Reports but is omitted in all Summary documents. Section 2.3.4.3.3 of the AR6 Working Group I report, entitled “global greening and browning,” points out that the IPCC Special Report on Climate Change and Land had concluded with *high confidence* that greening had increased globally over the past 2-3 decades. It then discusses that there are variations in the greening trend among data sets, concluding that while they have *high confidence* greening has occurred, they have *low confidence* in the magnitude of the trend. There are also brief mentions of CO₂ fertilization effects and improvements in water use efficiency in a few other chapters in the AR6 Working Groups I and II Reports.

Overall, however, the Policymaker Summaries, Technical Summaries, and Synthesis Reports of AR5 and AR6 do not discuss the topic.

2.2 The Alkaline Oceans

2.2.1 Changing pH

A neutral aqueous solution has a pH of 7.0, while one with pH greater than 7.0 is alkaline (also termed basic) and with pH less than 7.0 is acidic. The modern-day global average pH of surface sea water is estimated to be 8.04 (Copernicus Marine Service 2025, Figure 2.3), down from an estimated value of 8.2 in pre-Industrial times (Gattuso and Hansson, 2011). As CO₂ concentrations in the atmosphere increased, the oceans absorbed more, which decreases their pH. Depending upon the oceans’ buffering capacity, they are expected to become somewhat less alkaline over time, consistent with the observed decrease in pH.

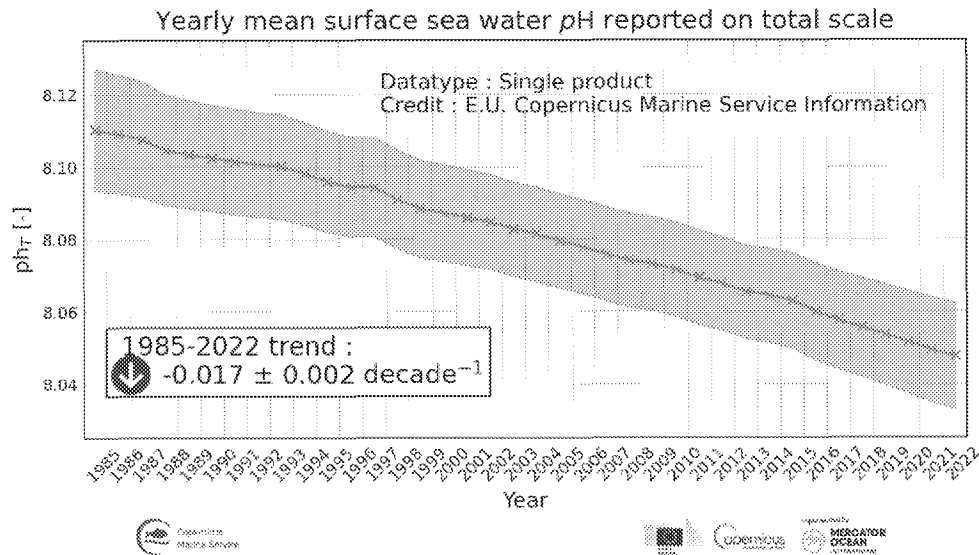


Figure 2.3: Ocean pH 1985 – 2022. Source: Copernicus Marine Service 2025

While this process is often called “ocean acidification”, that is a misnomer because the oceans are not expected to become acidic; “ocean neutralization” would be more accurate. Even if the water were to turn acidic, it is believed that life in the oceans evolved when the oceans were mildly acidic with pH 6.5 to 7.0 (Krissansen-Totton *et al.*, 2018). On the time scale of thousands of years, boron isotope proxy measurements show that ocean pH was around 7.4 or 7.5 during the last glaciation (up to about 20,000 years ago) increasing to present-day values as the world warmed during deglaciation (Rae *et al.*, 2018). Thus, ocean biota appear to be resilient to natural long-term changes in ocean pH since marine organisms were exposed to wide ranges in pH.

2.2.2 Coral reef changes

There are concerns that a decreasing pH of sea water will reduce the calcification rate of coral reefs. But coral reefs already endure large swings in pH, partly due to daily photosynthetic activity in the reef; measured pH values range from 9.4 during the day to 7.5 at night (Revelle and Fairbridge, 1957). De’ath *et al.* (2009) reported that a portion of Australia’s Great Barrier Reef (GBR, the world’s largest coral reef ecosystem) had experienced a 14 percent decline in calcification since 1990. This was tentatively attributed to increasing water temperature and decreasing pH. But Ridd *et al.* (2013) showed that report to have resulted from a biased data analysis that, when corrected, showed no change in calcification rates. Nevertheless, the alarm produced by the original paper has persisted as evidenced by the large number of published citations (541) to the original study compared to only 11 citations to the correction (as of 30 April 2025).

The most recent annual summary of GBR conditions from the Australian Institute of Marine Science indicates that coral production has rebounded strongly (AIMS, 2023). Figure 2.4 shows the results of the AIMS surveys of hard coral cover, expressed as a percentage of the reef area. Much of the decline in the GBR before 2011 turned out to be due to intense tropical cyclone activity (Beeden *et al.*, 2015) as well as a string of marine heatwaves, agricultural runoff and invasive species (Woods Hole, 2023). Given the reported declines in GBR calcification between 1990 and 2009 and the continued increase in atmospheric CO₂ levels, the rebound has surprised some observers.

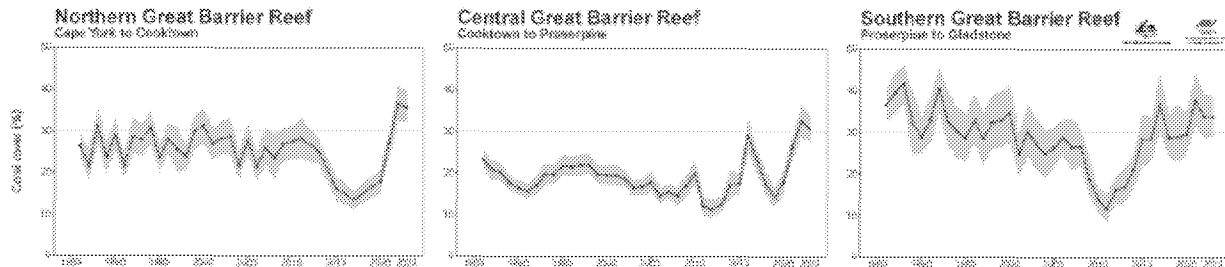


Figure 2.4 Hard coral cover of three regions of the Great Barrier Reef 1985 to 2023. Source: AIMS 2023.

It is being increasingly recognized that publication bias (alarming ocean acidification results preferred by high-impact research publications) exaggerates the reported impacts of declining ocean pH. An ICES Journal of Marine Science Special Issue addressed this problem with an article entitled, *Towards a Broader Perspective on Ocean Acidification Research*. In the Introduction to that Special Issue, H. I. Browman stated, “As is true across all of science, studies that report no effect of ocean acidification are typically more difficult to publish.” (Browman, 2016).

Similarly, a meta-analysis (Clements *et al.*, 2021) of the negative effects of ocean acidification on reef fish behavior found what they called a “decline effect”: initially dramatic conclusions published in prominent journals showing apparently large impacts of acidification tended to be followed up by subsequent studies on larger sample sizes yielding much smaller and typically non-existent effects. They call for their colleagues to improve research practices to counter the “decline effect”:

[The] vast majority of studies with large effect sizes in this field tend to be characterized by low sample sizes, yet are published in high-impact journals and have a disproportionate influence on the field in terms of citations. We contend that ocean acidification has a negligible direct impact on fish behavior, and we advocate for improved approaches to minimize the potential for a decline effect in future avenues of research (Clements *et al.*, 2021).

In summary, ocean life is complex and much of it evolved when the oceans were acidic relative to the present. The ancestors of modern coral first appeared about 245 million years ago. CO₂ levels for more than 200 million years afterward were many times higher than they are today. Much of the public discussion of the effects of ocean “acidification” on marine biota has been one-sided and exaggerated.

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3 HUMAN INFLUENCES ON THE CLIMATE

Chapter Summary:

The global climate is naturally variable on all time scales. Anthropogenic CO₂ emissions add to that variability by changing the total radiative energy balance in the atmosphere.

The IPCC has downplayed the role of the sun in climate change but there are plausible solar irradiance reconstructions that imply it contributed to recent warming.

Climate projections are based on IPCC emission scenarios that have tended to exceed observed trends. Most academic climate impact studies in recent years are based upon the extreme RCP 8.5 scenario that is now considered implausible; its use as a business-as-usual scenario has been misleading.

Carbon cycle models connect annual emissions to growth in the atmospheric CO₂ stock. While models disagree over the rate of land and ocean CO₂ uptake, all agree that it has been increasing since 1959.

There is evidence that urbanization biases in the land warming record have not been completely removed from climate data sets.

3.1 Components of radiative forcing and their history

3.1.1 Historical radiative forcing

A changing climate has been the norm throughout the Earth's 4.6-billion-year history. The Earth's temperature and weather patterns change naturally over timescales ranging from decades to millions of years. Natural variations in the surface climate originate in two ways. Internal climate fluctuations associated with circulations in the atmosphere and ocean exchange energy, water, and carbon between the atmosphere, oceans, land, and ice. External influences on the climate system include variations in the energy received from the sun and the effects of volcanic eruptions. Human activities influence climate through changing land use and land cover. Humans are also changing the composition of the atmosphere by emissions of CO₂ and other greenhouse gases and by altering the concentration of aerosol particles in the atmosphere.

The earth is warmed by the sunlight it absorbs and is cooled by the heat it radiates to space. Averaged over the Earth's surface, each of these processes involve power flows of about 240 Watts per square meter (W/m²). When they are in balance, there are no net external causes of warming or cooling. Both human and natural influences on the climate alter this balance and so cause the climate to change.

Influences on the Earth's energy balance at the top of the atmosphere are quantified by "radiative forcing", the extent to which they disturb the warming/cooling balance; a positive forcing warms while a negative forcing cools. The IPCC's estimated history of major components of radiative forcing since 1750 is shown in the following two figures from its AR6.

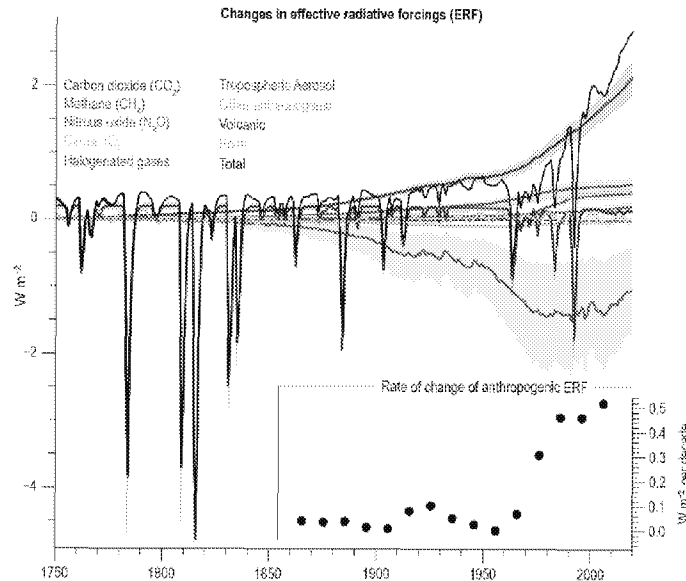


Figure 3.1.1: IPCC estimates of radiative forcing components over time. Shading indicates uncertainty ranges. Source: AR6 WGI Ch2 Fig. 10

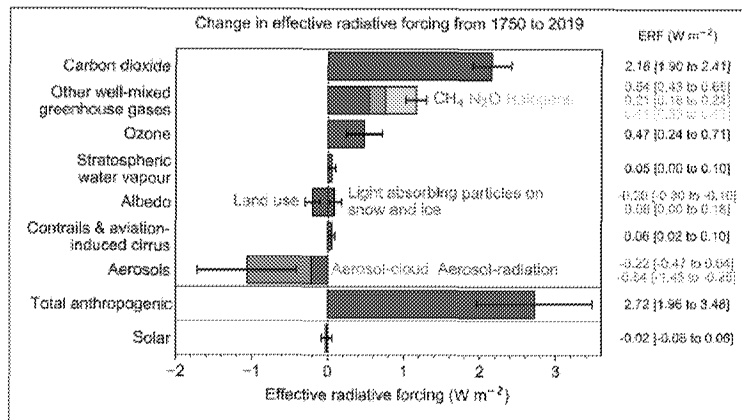


Figure 3.1.2 IPCC estimates of radiative forcing component changes from 1750 to 2019. Source: AR6 WGI Ch 7 Fig. 7-6.

These graphs show that the total radiative forcing is comprised of both natural and anthropogenic components. Carbon dioxide is the largest human influence on the climate and the one most relevant to the influence of fossil fuel use. It exerts a warming influence by decreasing the cooling power of the atmosphere. Emissions of CO_2 are accumulating in the atmosphere, as described in the following section, so that the warming influence is growing. Other greenhouse gases (methane, nitrous oxide, halogens, and ozone) act similarly, currently adding another 75 percent to CO_2 's warming. Aerosols exert an overall cooling effect, although with large uncertainties in the way they catalyze the formation of reflective clouds. As a result, understanding the causes of recent warming requires not just identifying the warming effects of CO_2 , but also the more uncertain cooling effects of aerosols.

The IPCC assesses the change in the radiative forcing by the sun to be negligible, based on their preference for data reconstructions that imply minimal solar change since preindustrial times. But Connolly *et al.* (2021) reviewed sixteen different Total Solar Irradiance (TSI) reconstructions in the literature

covering the years 1600-2000; the reconstructions vary from almost no change in TSI to a relatively large upward trend. Those authors note that the variation in TSI reconstructions combined with variations in surface temperature reconstructions allows for inferences consistent with either no or most 20th century warming being attributable to the sun.

A particularly thorny issue is the gap in TSI data between 1989 and 1991 due to a delay in the launch of a monitor following the Space Shuttle Challenger disaster on January 28 1986. This delay prevented a replacement satellite from being launched in time to overlap with, and its readings to be intercalibrated with, the prior system (Zacharias 2014, Scafetta *et al.* 2019). This is called the ACRIM (Active Cavity Radiometer Irradiance Monitor) gap problem. The question of whether there is an upward trend in TSI over 1978 to 2018 hangs on how the ACRIM data gap is filled. Connolly *et al.* (2021) found that the IPCC's consensus statements on solar forcing were formulated prematurely through the suppression of dissenting scientific opinions.

Another natural radiative forcing component is volcanic aerosols, which exert an episodic cooling influence. Box 4.1 in the IPCC AR6 Report addresses the climate impact of volcanic eruptions, noting three explosive volcanic eruptions that occurred in the first half of the 19th century. This included the 1815 Tambora eruption that resulted in the ‘year without summer’, with multiple harvest failures across the Northern Hemisphere. There is uncertainty about the sign of the relatively small forcing due to the submarine volcano Hunga Tonga which erupted in 2022 (Jenkins *et al.* 2023, Schoeberl *et al.* 2024).

Figure 3.1.1 shows that the anthropogenic forcing component was negligible before about 1900 and has increased steadily since, rising to almost 3 W/m² today. However, this is still only about 1 percent of the unperturbed radiation flows, making it a challenge to isolate the effects of anthropogenic forcing; state-of-the-art satellite estimates of global radiative energy flows are only accurate to a few W/m².

Natural sources of global energy imbalance other than volcanoes and total solar irradiance (TSI) are not included in these graphs because they remain largely unknown.

3.1.2 Change in atmospheric CO₂ since 1958

Carbon dioxide's warming influence depends on how much “extra” CO₂ accumulates in the atmosphere- *i.e.*, its concentration above the preindustrial value of 280 ppm. The CO₂ level as recorded at the Mauna Loa observatory in Hawaii, generally used as the representative global average concentration, is available online at [[HYPERLINK "https://gml.noaa.gov/ccgg/trends/index.html"](https://gml.noaa.gov/ccgg/trends/index.html)]. The concentration was about 316 ppm at the start of the record in 1959 and is now about 430 ppm, a 36 percent increase. At the end of the last glaciation CO₂ levels had fallen to about 180 ppm. As discussed in Chapter 2, C3 plants begin dying at CO₂ levels below about 140 ppm and C4 plants at levels below 100 ppm, so if CO₂ levels had continued falling plant life would have been imperiled.

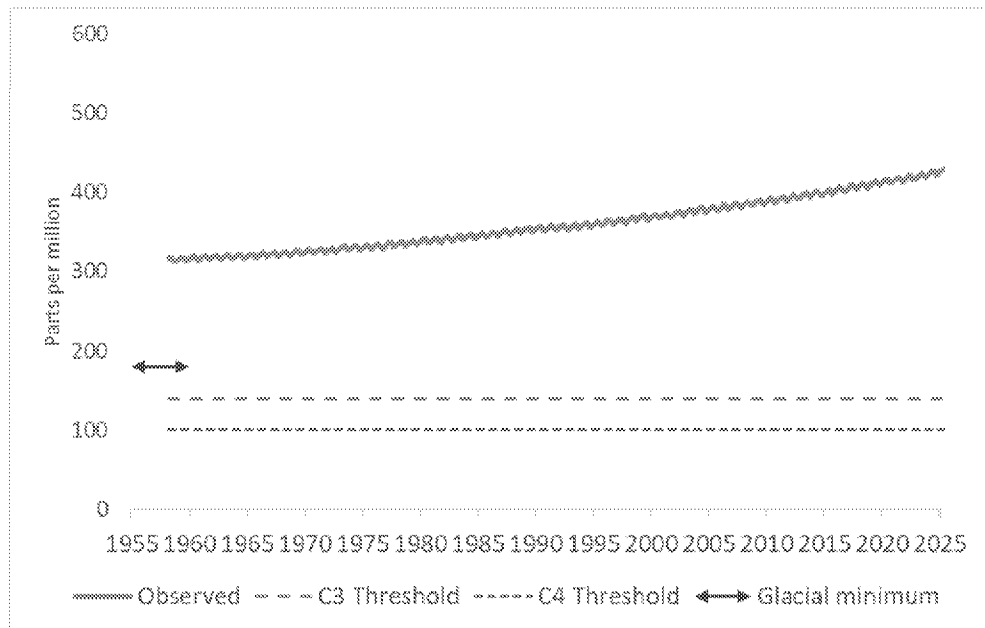


Fig. 3.1.3. Yearly average atmospheric CO₂ concentrations (1959-2025) in ppm measured at Mauna Loa (blue). C3 Threshold: Level below which C3 plants begin dying (140 ppm, see Chapter 2). C4 Threshold: Level below which C4 plants begin dying (100 ppm, see Chapter 2). Glacial minimum: Minimum level during recent glaciations (purple arrow). CO₂ data source: [HYPERLINK "<https://gml.noaa.gov/ccgg/trends/index.html>"]

The annual increase in concentration is only about half of the CO₂ emitted because land and ocean processes currently absorb “excess” CO₂ at a rate approximately 50 percent of the human emissions. Future concentrations, and hence future human influences on the climate, therefore depend upon two components: (1) future rates of global human CO₂ emissions, and (2) how fast the land and ocean remove extra CO₂ from the atmosphere. We discuss each of these in turn.

3.2 Future emission scenarios and the carbon cycle

3.2.1 Emission scenarios

Assessing the dangers of future GHG emissions requires assumptions about what those emissions will be. Future emissions, and hence human influences on the climate, will depend upon future demographics, economic activity, regulation, and energy and agricultural technologies. Various assumptions about each of those lead to projections of greenhouse gas emissions and concentrations, aerosol concentrations, and changes in land use, which ultimately can be combined into assumptions about anthropogenic radiative forcing.

The great uncertainties about these many factors make it impossible to precisely predict future emissions. Instead, the IPCC has used various sets of scenarios meant to span a plausible range of possibilities for population, economy, and technologies. Recent versions of the scenarios are labeled by a number indicating the anthropogenic radiative forcing expected in 2100 under that scenario. Thus, a scenario labeled with a “6” corresponds to 6 W/m² of human-induced radiative forcing (warming) at the end of the century. (Recall current anthropogenic radiative forcing is about 2.7 W/m².)

Although the IPCC does not claim its emission scenarios are forecasts, they are often treated as such. Comparisons of past scenario groups against observations show that IPCC emission projections have tended to overstate actual subsequent emissions. For the IPCC Third and Fourth Assessment Reports a set of emission projections from the *Special Report on Emission Scenarios* was used; these were referred to as the SRES scenarios. McKittrick *et al.* (2012) showed that, when converted to per capita values, the SRES scenario emissions distribution was skewed upwards compared with observed trends. The bias of the SRES scenarios was confirmed by the later analysis of Hausfather *et al.* (2019) who showed that observed atmospheric CO₂ concentrations tracked the low end of the SRES range and also of subsequent IPCC scenario ranges (Figure 3.2.1).

For AR5 the IPCC developed a new set of scenarios called the Representative Concentration Pathways (RCPs). These were identified by a number representing the increase in forcing and were thus called RCP2.6, RCP4.5, RCP6.0 and RCP8.5. RCP2.6 (implying an anthropogenic radiative forcing in 2100 of 2.6 W/m²) describes a GHG concentration pathway leading to warming well below 2°C. At the other end of the scale RCP8.5 is an extreme outcome implying nearly 5°C warming from 1900 to 2100.

RCP8.5 came to be referred to as the no-policy baseline, or “business-as-usual” scenario in both the academic literature and popular media. It was therefore used to generate the reference outcome supposedly representing the 21st century world in the absence of increasingly stringent emission reduction policies. But RCP8.5 was intended as a low-probability high emissions scenario and its use as a business-as-usual baseline has been criticized as grossly misleading.¹ Hausfather and Peters (2020a) writing in a commentary in *Nature*, pointed out that RCP8.5 was developed as an extreme worst-case, and its misuse as a “business as usual” baseline has resulted in a large number of misleading studies and media reporting.

The implausibility of the RCP8.5 scenario was examined by Burgess *et al.* (2021). The implausibility of RCP8.5 should not be interpreted as *very unlikely* (e.g. 95th percentile) or a “worst case”, but rather as genuinely implausible owing to the implausibility of the inputs required to reach a forcing of 8.5 W/m². They noted that RCP8.5 has already diverged from observed trends in energy use and the near future trends diverge sharply from those of the International Energy Agency (IEA), which provides market-based projections of energy use for the coming decades. Pielke Jr. *et al.* (2022) further showed that the historic and projected IEA trends run near the bottom of the envelopes of both RCP projections and the more recent Shared Socioeconomic Pathway (SSP) scenario trends.

Schwalm *et al.* (2020) defended the use of RCP8.5 on the grounds that cumulative CO₂ emissions over 2005-2020 track it more closely than the lower RCP scenarios. They also argue that a modified version of the IEA scenarios closely track RCP8.5 in the coming decades. Hausfather and Peters (2020b) responded that the skill of RCP8.5 over those 15 years is due to offsetting errors in its representation of CO₂ from fuel use and land use change, and the apparent agreement with IEA in coming decades is due to Schwalm *et al.* adding in very high land use emissions. The IEA’s own projected CO₂ emissions track well below RCP8.5.

Widespread use of RCP8.5 as a no-policy baseline has created a bias towards alarm in the climate impacts literature. The extent of this problem was confirmed in a literature analysis by Pielke Jr. and Ritchie (2020). They found that some 16,800 scientific papers published between 2010 and 2020 used the RCP8.5 scenario, with about 4,500 of the articles linking RCP8.5 to the concept of “business-as-usual”. Their analysis showed how RCP8.5 was misused not only by individual researchers, but also by influential science agencies like the IPCC and the U.S. National Climate Assessment (USNCA), which has directly led to misleading coverage in prominent media outlets.

¹ This extreme scenario is useful for modelers, since a large forcing generates a large response (warming) making it easier to assess a model’s sensitivity. But that’s very different than claiming it is a plausible future outcome.

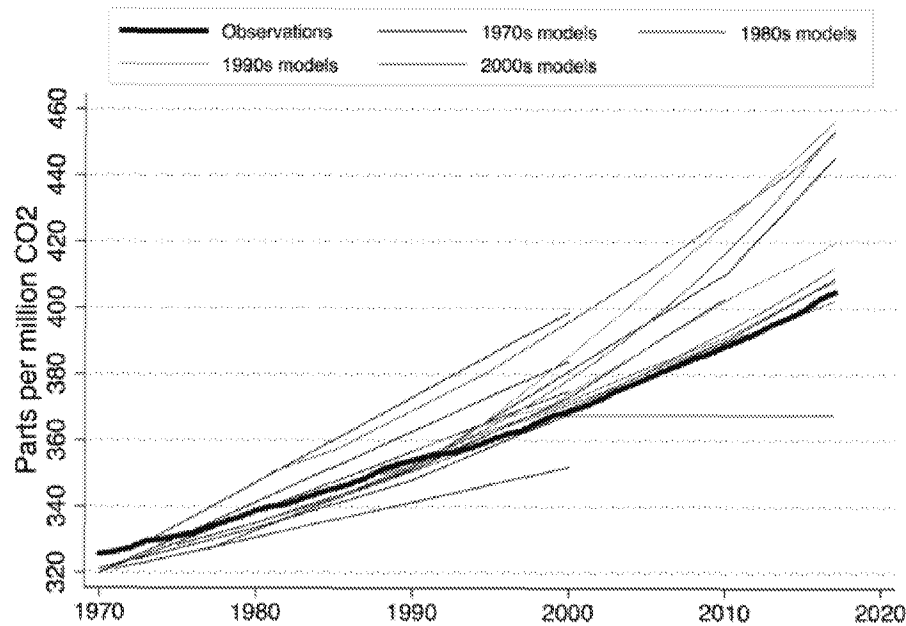


Figure 3.2.1 Since the 1970s successive families of emission and concentration projections (colored lines) have consistently overestimated observations (black line). Source: Hausfather *et al.* (2019) Figure S4.

Pielke and Ritchie (2020) reported new studies using RCP8.5 were published at a rate of about 20 per day, with about two per day specifically linking RCP8.5 and “business as usual.” They conclude that the climate research community has spent a decade “committing scientific resources to science fiction” and that “The scientific literature has become imbalanced in an apocalyptic direction.”

The IPCC developed a new set of scenarios for AR6, the “Shared Socioeconomic Pathway” (SSP) scenarios, which have continued the bias shown in the RCP and SRES scenarios. Figure 3.2.2 shows total global observed CO₂ emissions compiled by the International Energy Agency (IEA) merged with the emission projection from the IEA taking account of energy use projections and current policies. The other lines show the range of IPCC SSP scenarios (SSP1-SSP5). As of 2023, global CO₂ emissions have been tracking well below SSP7.0 and are even below SSP2-4.5.

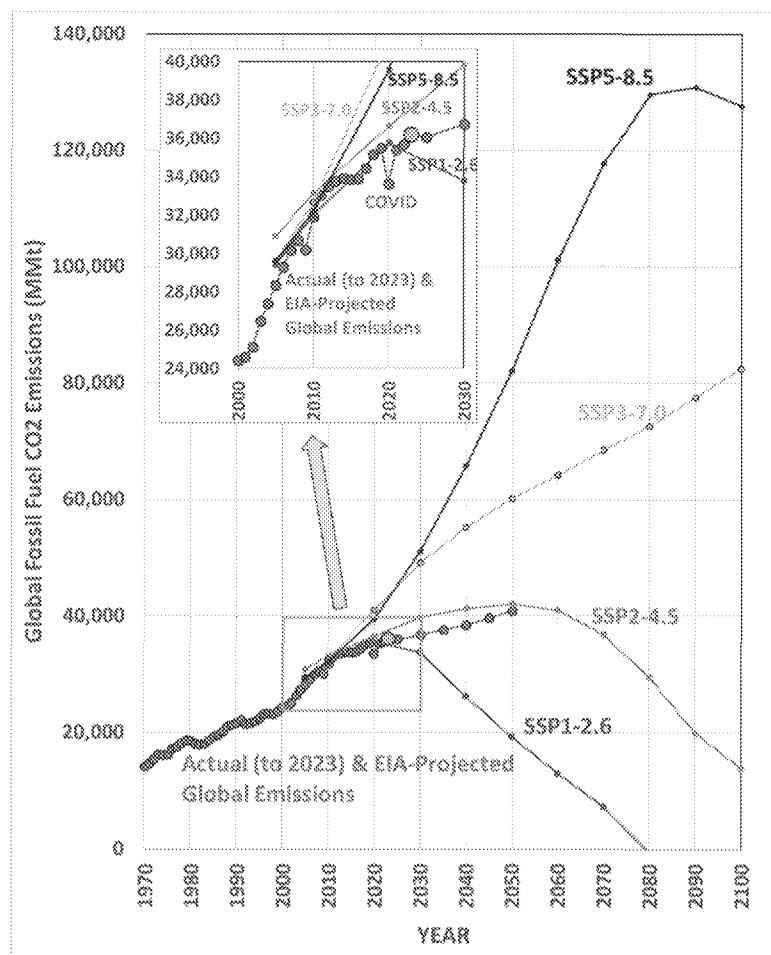


Figure 3.2.2. Observed and projected CO₂ emissions. Source: IPCC (SSP scenarios) and Energy Information Administration (EIA). Green: observed historical emissions and EIA projections. Other lines: SSP1-5. Data source: Friedlingstein *et al.* (2024).

3.2.2 The carbon cycle relating emissions and concentrations

Carbon dioxide emissions from fossil fuel burning (and to a lesser extent deforestation and cement production) have led to steadily increasing CO₂ concentrations in the atmosphere, as shown in Fig. 3.1.3. The relation between emissions and concentration is determined by the global carbon cycle of land and ocean processes that exchange carbon with the atmosphere. Our understanding of these processes was reviewed by Crisp *et al.* (2021).

There are about 850 Gt of carbon (GtC) in the Earth's atmosphere², almost all of it in the form of CO₂. Each year, biological processes (plant growth and decay) and physical processes (ocean absorption and outgassing) exchange about 200 GtC of that carbon with the Earth's surface (roughly 80 GtC with the land and 120 GtC with the oceans). Before human activities became significant, removals from the atmosphere were roughly in balance with additions. But burning fossil fuels (coal, oil, and gas) removes carbon from the ground and adds it to the annual exchange with the atmosphere. That addition (together with a much

² Because CO₂ is chemically transformed through the course of the carbon cycle, it is more convenient to track atoms of carbon rather than molecules of CO₂. One gigatonne of carbon (GtC) is equivalent to about 3.7 Gt of CO₂.

smaller contribution from cement manufacturing) amounted to 10.3 GtC in 2023, or only about 5 percent of the annual exchange with the atmosphere.

The carbon cycle accommodates about 50 percent of humanity’s small annual injection of carbon into the air by naturally sequestering it through plant growth and oceanic uptake, while the remainder accumulates in the atmosphere (Ciais *et al.*, 2013). For that reason, the annual increase in atmospheric CO₂ concentration averages only about half of that naively expected from human emissions.

To project future CO₂ concentrations in the atmosphere, and hence future human influences on the climate, it is important to know how the carbon cycle might change in the future. The historical near constancy of that 50 percent fraction means that the more CO₂ humanity has produced, the faster nature removed it from the atmosphere. That 50 percent fraction changes somewhat from year to year due to natural carbon cycle imbalances from El Nino, La Nina, and varying weather patterns. There was also a substantial additional reduction in atmospheric CO₂ after the 1991 eruption of Mt. Pinatubo, a curious result that has yet to be explained (Angert *et al.*, 2004).

The main processes that remove excess CO₂ from the atmosphere are increased growth of land vegetation (especially at high latitudes), some increase in the sequestering of carbon in soils, and uptake of CO₂ by the ocean due to the increasing partial pressure of atmospheric CO₂ over that of CO₂ dissolved in the ocean. All twenty land carbon cycle models tracked by the Global Carbon Project (Friedlingstein *et al.*, 2024) show land processes have been removing excess CO₂ at an increasing rate since 1959. This is consistent with a “global greening” phenomenon (Chapter 2.1) observed by satellites since monitoring of global greenness began in 1982.

While land vegetation has been responding positively to more atmospheric CO₂, uptake of extra CO₂ by ocean biological processes remains too uncertain to be measured reliably. Our current understanding of these and many more carbon cycle processes was reviewed by Crisp *et al.* (2021).

CO₂ uptake by land processes

The uptake of extra CO₂ from the atmosphere by land surface processes (as also inferred from global greening) has been modeled with 20 different dynamic global vegetation models, the outputs of which are updated every year by the Global Carbon Project (Friedlingstein, 2024). As seen in Fig. 3.2.3, all of those models agree that vegetation and soils have been sequestering carbon from the atmosphere. But we also see that the long-term trends over 1959 to 2023 (65 years) vary widely between models, by nearly a factor of 7. This demonstrates that there remains considerable uncertainty in how fast land processes are removing CO₂ from the atmosphere, which in turn creates uncertainty in future atmospheric CO₂ concentrations, which then produce uncertainty in climate model simulations of future climate change.

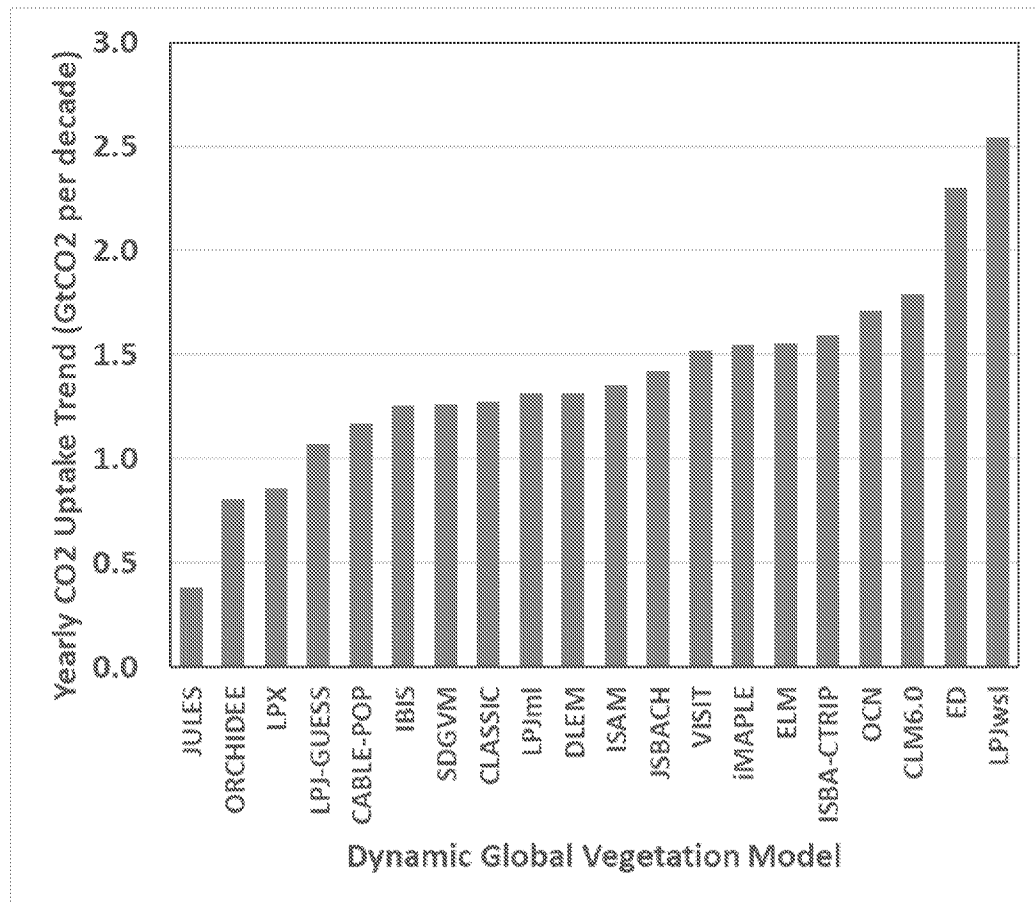


Figure 3.2.3 Trends of annual CO₂ uptake (GtCO₂ per year per decade) by land processes during 1959-2023 simulated by 20 different dynamic global vegetation models periodically reported by the Global Carbon Project (Friedlingstein, 2024).

CO₂ uptake by ocean processes

The uptake of extra CO₂ from the atmosphere by ocean processes has been modeled with 10 different ocean biogeochemistry models, the outputs of which are updated every year by the Global Carbon Project (Friedlingstein, 2024). Like the results from the land models, all of the ocean models agree that the global oceans have been sequestering carbon from the atmosphere at an increasing rate during 1959-2023 (Fig. 3.2.4). Unlike the land models, however, the ocean models show much better agreement with each other, with the model producing the fastest increasing CO₂ uptake being only 65 percent faster than the model with the most slowly increasing CO₂ uptake. In spite of the relative agreement among models, Friedlingstein *et al.* (2022) notes that there is substantial discrepancy between the different methods on the strength of the ocean sink over the last decade, particularly in the Southern Ocean.

Note that the average trend in CO₂ uptake across all land models in Fig. 3.2.3 is 25 percent larger than the average trend in ocean uptake. This suggests land processes are increasing in their ability to remove CO₂ faster than ocean processes are increasing their CO₂ sequestration.

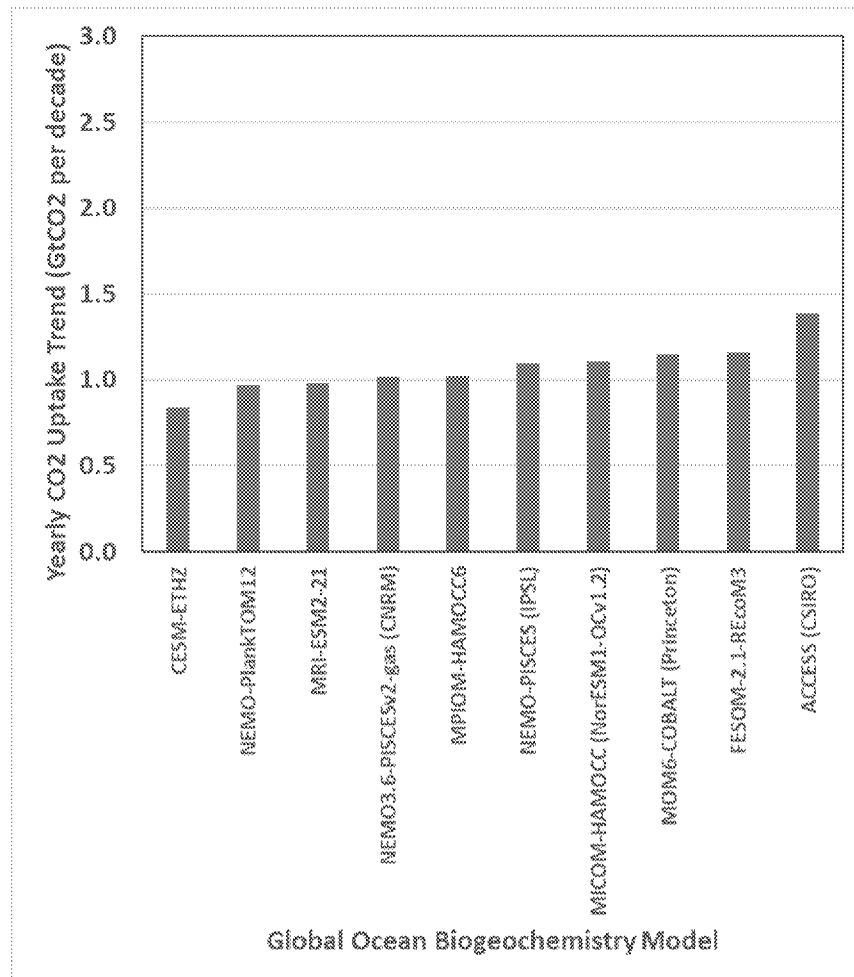


Figure 3.2.4 Trends of annual CO₂ uptake (GtCO₂ per year per decade) by ocean processes during 1959-2023 simulated by 10 different ocean biogeochemistry models periodically reported by the Global Carbon Project (Friedlingstein, 2024).

3.3 Urbanization influence on temperature trends

Historical temperature data over land has been collected mainly where people live. This raises the problem of how to filter out non-climatic warming signals due to Urban Heat Islands (UHI) and other changes to the land surface. If these are not removed the data might over-attribute observed warming to greenhouse gases. The IPCC acknowledges that raw temperature data are contaminated with UHI effects but claims to have data cleaning procedures that remove them. It is an open question whether those procedures are sufficient.

AR6 downplayed this issue by saying (WGI p. 235) that no recent evidence had emerged to alter the AR5 finding that urbanization causes an upward bias of no more than 10 percent in the global land surface warming trend. AR5 (WGI p. 189) also cited the 10 percent upper bound without citing a source. AR4 (WGI p. 244) cited Jones *et al.* (1990) and Peterson *et al.* (1999) as the basis of the claim. Peterson *et al.* had failed to find any difference in trends between rural and urban samples, although their definition of rural included local populations up to 10,000 persons while the relative influence of urbanization begins well below that (Spencer *et al.*, 2025). Jones *et al.* compared rural/urban warming in three regions: Eastern Australia, Eastern China and Western Soviet Union. Their definition of “rural” included towns of up to

10,000 in the former Soviet Union and up to 100,000 in China. They found relative warming biases greater than 10 percent in these areas but conjectured that the urbanization effect averaged over the areas they did not examine would bring the global land bias to under 10 percent of the observed warming trend.

Several papers appeared in print prior to the IPCC AR4 that argued that the warming effect of UHIs added a relatively large (30-50%) component to observed warming and was not simulated by climate models (de Laat and Maurellis 2006, McKittrick and Michaels 2007). These findings were based on correlations between locations of maximum warming over land with locations of maximum socioeconomic development. AR4 asserted (p. 244) that these correlations were an artefact of natural atmospheric circulations and were in fact statistically insignificant, and on that basis set the findings aside. Their claim was controversial because it was presented with no supporting evidence. McKittrick (2010) and McKittrick and Nierenberg (2010) showed that taking into account various conjectured alternative explanations for the correlations did not affect their significance. AR5 (p. 189) conceded that AR4 had provided “no explicit evidence” for its assessment and further acknowledged, based on these papers, that there was “significant evidence for such contamination of the record” i.e. a warming bias in the land record. However as already noted, elsewhere in the AR5 report they carried forward AR4 claim that it was less than 10 percent of observed warming. Further they provided no caution about using the land record for climate measurement despite conceding the evidence for UHI contamination. Recently Soon *et al.* (2023) estimated an urbanization bias in the Northern Hemisphere land record over 1850-2018 sufficient to increase the trend in the blended record from 0.55°C to 0.89°C per century.

Some studies providing evidence against UHI contamination compared warming rates between rural and urban locations (Jones *et al.* 1990, Peterson *et al.* 1999, Wickham *et al.* 2013). It is not known whether such methods would be capable of detecting UHI bias even when present. The influence of UHI warming is logarithmic in population, in other words it is strongest at low population density then levels off as local urbanization expands (Oke 1973, Spencer *et al.* 2025). Hence failure to find a difference in warming rates between urban and rural stations does not prove the absence of UHI contamination. McKittrick (2013) provided an empirical demonstration in which the rural/urban trends were not significantly different in a data set shown on other grounds to be contaminated with UHI bias.

Parker (2006) examined a sample of urban locations and found no difference in trends between subsets partitioned according to nighttime wind speed, concluding on this basis that urbanization could not be a significant factor. Here again the question is whether such a method would find UHI bias even if present. McKittrick (2013) presented an example in which UHI-contaminated data did not exhibit significant trend differences when stratified according to wind speed.

The challenge in measuring UHI bias is relating local temperature change to a corresponding change in population or urbanization, rather than to a static classification variable such as rural or urban. Spencer *et al.* (2025) used newly available historical population archives to undertake such an analysis and found evidence of significant UHI bias in U.S. summertime temperature data.

In summary, while there is clearly warming in the land record, there is also evidence that it is biased upward by patterns of urbanization and that these biases have not been completely removed by the data processing algorithms used to produce climate data sets.

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PART II: CLIMATE RESPONSE TO CO₂ EMISSIONS

4 CLIMATE SENSITIVITY TO CO₂ FORCING

Chapter Summary

There is growing recognition that climate models are not fit for the purpose of determining the Equilibrium Climate Sensitivity (ECS) of the climate to increasing CO₂. The IPCC has turned to data-driven approaches including historical data and paleoclimate reconstructions, but their reliability is diminished by data inadequacies.

Data-driven ECS estimates tend to be lower than climate model-generated values. The IPCC AR6 upper bound for the likely range of ECS is 4.0°C, lower than the AR5 value of 4.5°C. This lowering of the upper bound seems well justified by paleoclimatic data. The IPCC AR6 lower bound for the likely range of ECS is 2.5°C, substantially higher than the AR5 value of 1.5°C. This raising of the lower bound is less justified; evidence since the AR6 finds the lower bound of the *likely* range to be around 1.8°C.

4.1 Introduction

The magnitude of the climate's response to increasing concentrations of CO₂ is central to the scientific debate on anthropogenic climate change, and so also to the public debate on "climate action." The simplest measure of that response is the rise in the global average surface temperature, quantified by the Equilibrium Climate Sensitivity (ECS). ECS is defined as the amount of warming expected in response to a doubling of CO₂ from its pre-industrial concentration of 280 ppm, after all climate components have had time to adjust. Some components, like temperatures in the lower atmosphere (troposphere), adjust rapidly, while others such as the deep ocean and cryosphere might take as long as centuries. A related measure, the Transient Climate Response (TCR), better describes the shorter time scales; it is defined as the amount of warming when the CO₂ concentration is doubled by rising one percent annually for 70 years.

The 1979 Charney Report for the U.S. National Academy of Sciences (National Research Council 1979) proposed that the most likely ECS was $3.0 \pm 1.5^\circ\text{C}$. The IPCC repeatedly reaffirmed that range with only minor variations until its most recent AR6. AR5 termed 1.5–4.5°C as the *likely* range (66 percent probability) and stated that ECS is *extremely unlikely* (95 percent probability) to be below 1.0°C and *very unlikely* (90 percent probability) to exceed 6.5°C.

The uncertainty in ECS has remained stubbornly wide, despite many individual studies that claimed to narrow it (Hausfather 2023). Most recently, AR6 narrowed the *likely* range to 2.5–4.0°C and deemed the *very likely* range to be 2.0–5.0°C. This narrowing on the low end is disputed, as will be discussed below.

Uncertainties in ECS are highly consequential for policy making. As will be discussed in Chapter 11, economic models use ECS values to project the costs of CO₂ emissions. The traditional value (3.0 °C) has typically yielded modest global social costs of CO₂ emissions, sufficient to justify some policy actions, but mostly deferred to later in this century. If ECS is very high (above 4.5°C) immediate aggressive emission controls become more imperative, whereas no CO₂ emission controls are economically justifiable for ECS below 2.0°C (Dayaratna *et al.* 2017, 2020). Obtaining a precise estimate is impossible, so policy making needs to account for the uncertainty.

By itself, the equilibrium warming effect of a doubling of atmospheric CO₂ is slightly more than 1°C (Soden and Held 2006). Larger values of ECS arise from positive feedbacks that amplify the CO₂ warming. Water vapor feedback is positive: a warmer atmosphere might have more water vapor, which itself is a powerful greenhouse gas. Warmer temperatures also result in less snow and sea ice cover, allowing the

Earth to absorb more of the sun's radiation. Some simple estimates of these feedbacks increase the ECS to around 2°C (Sherwood *et al.*, 2020). Larger values of ECS are associated with positive cloud feedbacks.

Climate scientists use multiple lines of evidence to determine the Equilibrium Climate Sensitivity:

- Climate model simulations
- Historical observations
- Paleoclimatic reconstructions
- Process understanding of feedbacks

4.2 Model-based estimates of climate sensitivity

The ECS ranges given in IPCC AR4 and AR5 were obtained primarily by examining the behavior of large-scale climate models, also called General Circulation Models (GCMs). However, the IPCC changed course in its AR6 when it turned to a more direct data-driven methodology. Here we discuss some of the pitfalls of using GCMs to try to determine the Earth's climate sensitivity.

In principle, ECS is an emergent property of GCMs—that is, it is not directly parameterized or tuned, but rather emerges in the results of the simulation. Otherwise plausible GCMs and parameter selections have been discarded because of perceived conflict with an expected warming rate, or aversion to a model's climate sensitivity being outside an accepted range (Mauritsen *et al.* 2012). This practice was commonplace for the models used in AR4; modelers have moved away from this practice with time. However, even in a CMIP6 model, Mauritsen and Roeckner (2020) state the following regarding their Max Planck Institute (MPI) climate model (emphasis added):

“We have documented how we tuned the MPI-ESM1.2 global climate model to match the instrumental record of warming; an endeavor which has clearly been successful. Due to the historical order of events, the choice was to do this practically by **targeting an ECS of about 3 K using cloud feedbacks**, as opposed to tuning the aerosol forcing.”

In other words, the MPI modelers chose an ECS value of 3°C and then tuned the cloud parameterizations to match their intended result.

As noted, direct warming from CO₂ doubling is only about 1°C (Soden and Held 2006); further warming arises from climate feedbacks that are not explicitly resolved by the GCM but rely on parameterizations of physical processes. Higher values of ECS arise primarily from positive cloud feedbacks, whereas the magnitude and even the sign of the feedbacks are very uncertain. Elements of cloud feedback include changes in the latitudinal distribution of clouds, changes in the distribution of cloud height (changes in low versus high clouds), changes to the phase of clouds (ice versus liquid), changes in cloud particle size (associated with changes in concentration and/or composition of aerosol particles), changes in the precipitation efficiency of clouds, and even changes in how clouds are distributed over the daily solar cycle (Curry and Webster, 1999). It is difficult for GCMs to simulate any of these processes correctly owing to their small scale, let alone predict how they will change in the future. Further, cloud processes modulate the magnitudes of the water vapor, lapse rate, and the surface albedo feedbacks.

ECS can be determined from climate model simulations by doubling the concentration of CO₂ and allowing several centuries for the warming to equilibrate. To avoid the need for such long simulations, “effective climate sensitivity” is commonly evaluated from a 150-year simulation in response to a sudden quadrupling of CO₂.

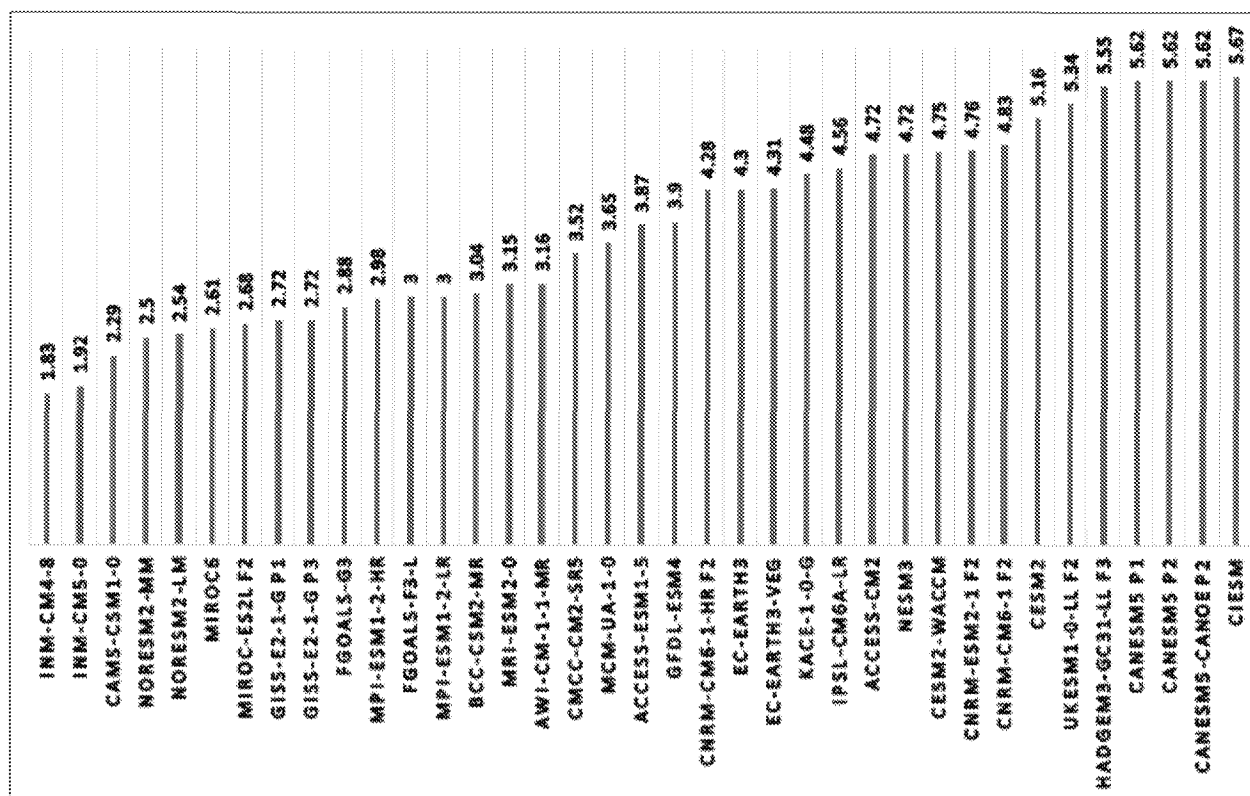


Figure 4.1 Equilibrium Climate Sensitivities in °C of 37 climate models from the CMIP6 ensemble. Identifiers for the various models appear along the horizontal axis. From (Scafetta, 2021)

The spread of ECS values from the CMIP5 ensemble of climate models used in AR5 was 2.0–4.7°C; that range increased for the CMIP6 models used in AR6 to between 1.8 and 5.7°C (Chen *et al.*, 2021, Scafetta 2021, see Figure 4.1). Far from resolving the model-based climate sensitivity the range appears to be growing. The main cause of the overall upward shift in ECS in CMIP6 relative to CMIP5 is a larger positive cloud feedback, driven by changes to the cloud parameterizations in many CMIP6 models (Zelinka *et al.*, 2020)

Because of concerns about model tuning and the high sensitivity to cloud parameterizations, the IPCC AR6(2021) did not rely on climate model simulations in their assessment of climate sensitivity, relying instead on data-driven methods.

4.3 Data-driven estimates of climate sensitivity

Climate sensitivity can also be estimated from instrumental records of surface temperatures and ocean heat content, combined with estimates of how climate forcings (e.g., greenhouse gases, solar, volcanoes, aerosols) have changed in the past (Otto *et al.*, 2013). Using this information, a simple empirical model called an Energy Balance Model can be employed. It requires estimating a feedback parameter whose uncertainties are highly amplified in the resulting ECS (Roe and Baker, 2007).

The accuracy of the data-driven methods depends on the quality of the input data. Assumptions are needed about ocean heat storage, and good data is only available for recent decades. The greatest source of

uncertainty is the amount and composition of aerosol particles and their interactions with cloud radiative properties (the so-called aerosol indirect effect; see Figures 3.1.1, 3.1.2). Climate models exhibit warming in response to GHGs but cooling in response to aerosols (Schwartz *et al.*, 2007). Observed 20th century warming can be shown to be consistent either with low ECS and low aerosol cooling, or high ECS and high aerosol cooling. Since fossil fuel use adds both GHGs and aerosols to the atmosphere, both effects need to be estimated to isolate the warming effect of CO₂.

Paleoclimate proxies are also used to evaluate the sensitivity of past climates by comparing paleoclimate changes in the Earth's temperatures to estimates of changes in forcings. The two most informative periods are the last glacial maximum (around 20,000 years ago), which was about 3–7°C colder than today, and a mid-Pliocene period (roughly three million years ago), which was 1–3°C warmer than today. The limits on cooling during the last glacial maximum give the best single evidence that high values of climate sensitivity are unlikely. However, paleoclimate estimates are associated with very large uncertainties in the estimated temperatures and forcings. Further, estimates of climate sensitivity based on past climate states might not be applicable to the current state of the climate system.

A recurring theme in the climate literature is that ECS estimates based on historical data are smaller than ECS estimates inferred from climate models (Sherwood and Forest 2024). About 15 estimates based on historical data appeared in the peer-reviewed literature between 2012 and 2024 yielding ECS best estimates between 1.0°C and 2.5°C, although critics have questioned some of the methods and the data quality. For AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical data and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6–3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective Bayesian priors in the analysis. Lewis' analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis – median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent. The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

An argument emphasized in AR6 is that data-driven ECS estimates might understate the future warming response to GHGs because of a so-called “pattern effect” (Forster *et al.*, 2021). The tropical Pacific is believed to strongly influence the overall efficiency with which the Earth radiates heat to space, but some regions remove heat more efficiently than others. If the west-to-east temperature gradient in the tropical Pacific is weakened in a warming climate, warming would concentrate where heat is less efficiently removed, raising ECS.

Most climate models simulate that rising GHGs will weaken the west-east temperature gradient, which led the IPCC in AR6 to conclude that data-driven ECS estimates understated the *future* ECS value. However, Seager *et al.* (2019) pointed out that, contrary to models, the west-east temperature gradient has been strengthening over time. They further argued that the mechanism predicting otherwise in climate models was based on a faulty characterization of oceanic dynamics and there is no reason to expect the gradient to weaken. A similar argument was recently made by Lee *et al.* (2024), who concluded that “the trajectory of the observed trend reflects the response to increasing GHG loading in the atmosphere”; in other words, GHG warming should lead to a future strengthening rather than a weakening of the temperature gradient. Increased efficiency of atmospheric cooling implies, if anything, that the future ECS in a warming climate might be *lower* than current estimates.

4.4 Transient Climate Response

The Transient Climate Response (TCR) provides a more useful observational constraint on climate sensitivity. TCR is the global temperature increase that results when CO₂ is increased at an annual rate of 1 percent over a period of 70 years (*i.e.*, doubled gradually). Relative to the ECS, observationally determined values of TCR avoid the problems of uncertainties in ocean heat uptake and the fuzzy boundary in defining equilibrium arising from a range of timescales for the longer-term feedback processes (*e.g.*, ice sheets). TCR is better constrained by historical warming, than ECS. IPCC AR6 judged the *very likely* range of TCR to be 1.2–2.4°C. In contrast to ECS, the upper bound of TCR is more tightly constrained. For comparison, the TCR values determined by Lewis (2023) are 1.25 to 2.0°C, showing much better agreement with AR6 values than was seen in a comparison of the ECS values.

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5 DISCREPANCIES BETWEEN MODELS AND INSTRUMENTAL OBSERVATIONS

Chapter summary

Climate models show warming biases in many aspects of their reproduction of the past several decades. In response to estimated changes in forcing they produce too much warming at the surface (except in the models with lowest ECS), too much warming in the lower- and mid-troposphere and too much amplification of warming aloft.

Climate models also produce too much recent stratospheric cooling, invalid hemispheric albedos, too much snow loss, and too much warming in the Corn Belt. The IPCC has acknowledged some of these issues but not all.

5.1 Introduction

Climate models are the primary tool used to project future climate changes in response to increasing atmospheric levels of anthropogenic greenhouse gases. To assess the fitness of climate models for this purpose, it is reasonable to ask how well they reproduce the current climate and its variations over the past century. The box “Climate modeling” gives some detail on how climate models work.

Of great concern is the fact that, after several decades of the climate modeling enterprise involving approximately three dozen models operated by research centers around the world, the range of future warming they produce in response to a hypothetical doubling of atmospheric CO₂ extends over a factor of three, as we discussed in the previous chapter. This range of disagreement among models has not decreased for decades.

Problems with climate models are not just in their disagreement over the future, but also in their ability to replicate the recent past. Here we review some of the most important metrics of climate model accuracy: ability to reproduce historical surface, tropospheric and stratospheric temperature trends; ability to reproduce the vertical warming profile; and ability to reproduce other climate features such as snowfall. In all cases a persistent finding is that models on average err on the side of too much warming in response to estimated historical forcings.

BOX: Climate modeling

Most climate models, except for the simplest ones, represent Earth's land surface using a grid of squares on the order of 100 km wide. To simulate the atmosphere, typically 30 or more grid boxes are stacked above these squares. The ocean is modeled using a similar but finer grid, resulting in tens of millions of grid boxes for the atmosphere and oceans.

The computer models, based on physical laws, calculate how air, water, and energy move between grid boxes over time. The time step can be as small as 10 minutes, and repeating this process millions of times allows the simulation of climate over centuries. Running these models, even on the most powerful supercomputers, can take months. Comparing simulation results with historical climate data helps assess the accuracy of a model, while projections into the future estimate climate changes under assumed human and natural influences.

Despite sounding straightforward, climate modeling is highly complex. Many critical processes occur at scales smaller than the grid size. For instance, the flows of sunlight and heat in the atmosphere depend strongly on cloud cover. Since tracking individual clouds is impractical, researchers must make “subgrid” assumptions about the distribution of clouds in each grid box. Snow and ice cover, which affects how much sunlight is reflected or absorbed by the surface, is another subgrid factor.

Each subgrid assumption requires numerical parameters, which must be carefully set. Modelers initially estimate these parameters based on physics and observed climate patterns, then run the model. Because early results often diverge significantly from real-world observations, they “tune” these parameters to better match observed climate features. Different modeling teams use distinct assumptions and tuning strategies, leading to varied outcomes. Tuning is a necessary but delicate aspect of climate modeling, as it is for any complex system. Poor tuning can result in inaccurate simulations, while excessive tuning risks artificially steering results toward predetermined conclusions.

The spread of model representations of the current climate is very wide. One of the most basic indicators—Earth's average surface temperature—varies by about 3°C across CMIP6 models prior to 1880 (Figure 5.1), narrows slightly until 2040 then diverges to over 4 °C. For comparison 20th century warming was only about 1.0°C. This variation suggests substantial differences among models' physical processes.

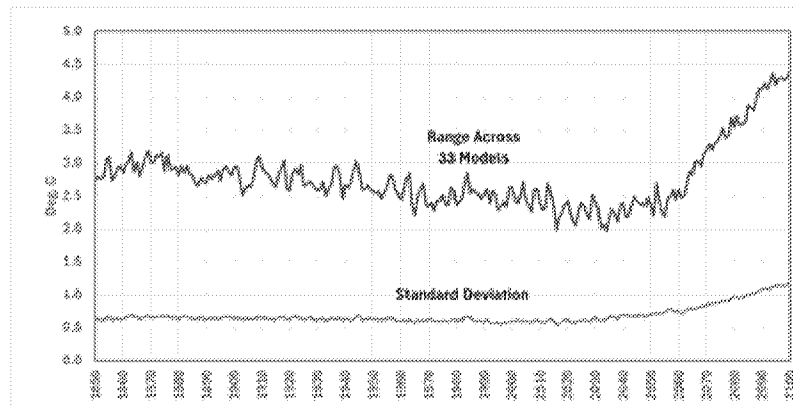


Figure 5.1 CMIP6 Average surface temperature range across 33 models and standard deviation using SSP5-85 scenario. Data from KNMI Climate Explorer website at [[HYPERLINK "https://climexp.knmi.nl/start.cgi" \t "_blank"](https://climexp.knmi.nl/start.cgi?_t=_blank)].

Beyond the models' ability to reproduce features of today's climate, the critical issue for society is how well they predict responses to subtle human influences, such as greenhouse gas emissions, aerosol cooling, and land-use changes. The most crucial aspect that models must capture correctly is “feedbacks.” These occur when climate changes either amplify or suppress further warming. In general, the modeled net effect of all feedbacks doubles or triples the direct warming impact of CO₂.

5.2 Surface warming

A straightforward test of a climate model's validity is its ability to reproduce historical warming in response to known past changes in climate drivers such as greenhouse gases. Figure 5.2 is reproduced from Scafetta (2023), that groups the latest-generation (CMIP6) climate models into low ECS (1.5 to 3.0 degrees C), medium ECS (3.0 to 4.5 degrees C) and high ECS (4.5 to 6.0 degrees C), and compares their post-1980 global average temperature simulation ranges to those of three surface temperature records and one satellite-based lower troposphere temperature data product.

The leftmost column shows that the low-ECS models track the post-1980 historical warming record reasonably well, but the middle and right columns show that the medium- and high-ECS models conspicuously over-predict the warming.

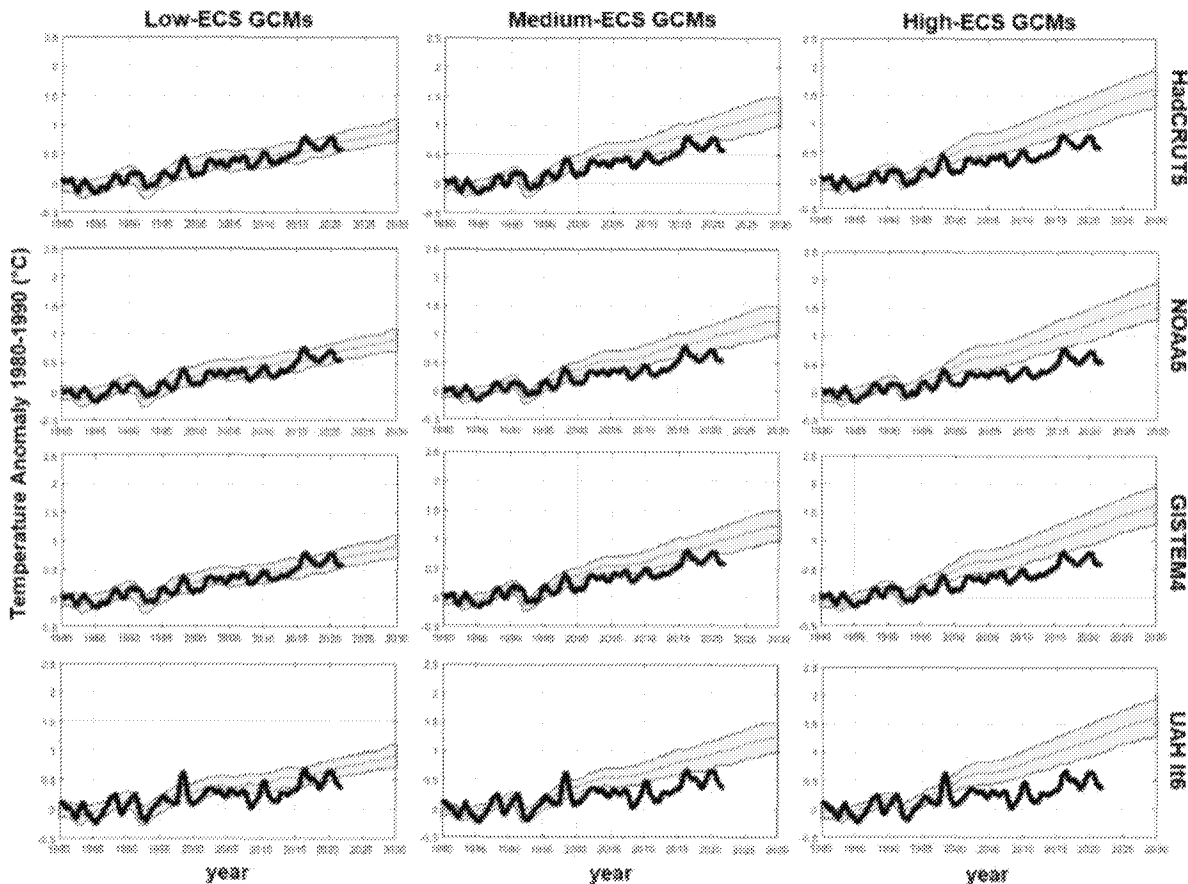


Figure 5.2: Model-Observational comparisons for Earth's surface warming. The columns correspond to model groups showing low-ECS (13 models) medium-ECS (11 models) and high-ECS (14 models), while the rows correspond to widely-used observed temperature records, the first three showing surface averages and the fourth showing the lower troposphere average. In each panel the yellow area denotes the mean and range ($\pm$ one standard deviation) of climate model simulations for that group. The thick black line shows the observed annual average temperature in the indicated source. Source: Scafetta (2023) Fig.2.

Spencer (2024) has also provided a useful summary of the Model-Observation mismatch by comparing trends in surface temperature data products with those in individual climate models, as summarized in Figure 5.3; most climate models show substantially more warming than the observations since 1979.

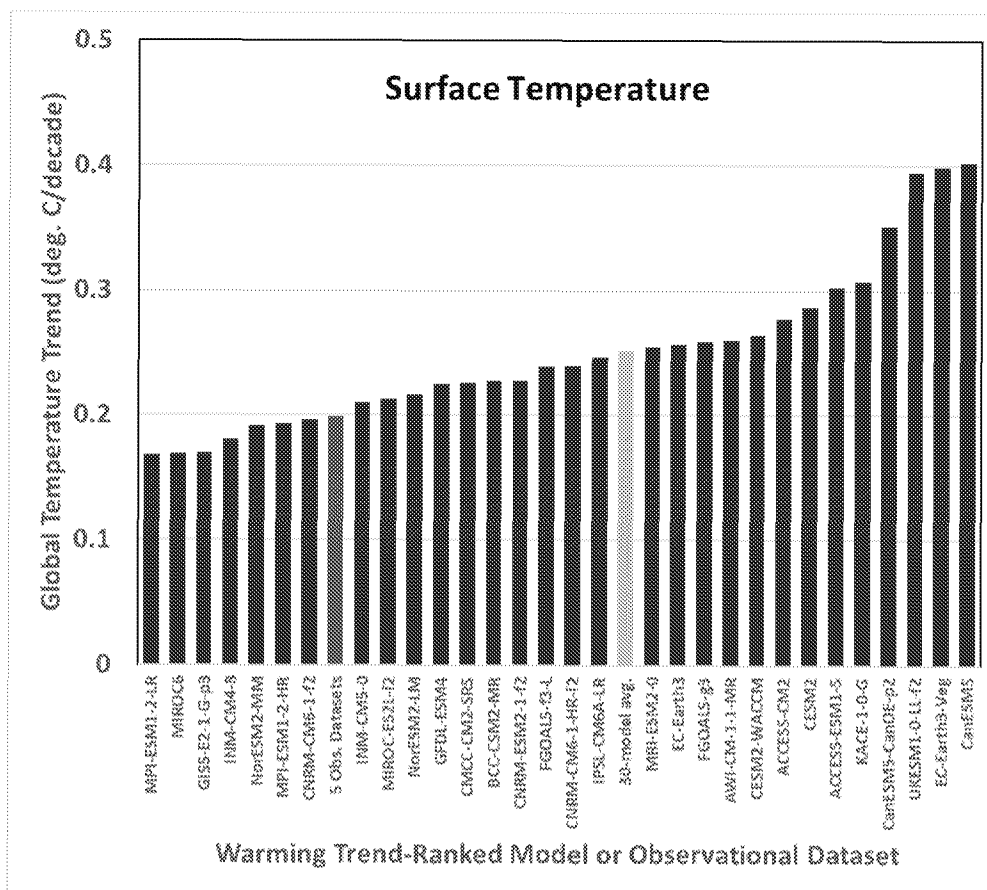


Figure 5.3 Global surface air temperature trends ($^{\circ}\text{C}/\text{decade}$), 1979-2024, from various CMIP6 climate models (red, 30-model average in orange); and the average of three thermometer datasets (HadCRUT5, NOAA Global Temp, and Berkeley 1 deg.) and two reanalysis datasets (ERA5 and NCEP/NCAR R1) in blue. Data source: <https://climexp.knmi.nl/start.cgi>.

5.3 Tropospheric warming

It has long been known that climate models on average overstate warming in the tropical troposphere. This region is an important test of climate models since this is where the signal of anthropogenic greenhouse warming emerges first and most strongly. Biases in tropospheric trends indicate model flaws in heat transfer processes that carry over to surface warming biases.

The discrepancy was flagged as a serious inconsistency in the first U.S. Climate Change Science Program report (Karl *et al.* 2006) and has been mentioned in every IPCC report since, but the discrepancy has gotten worse over time, and the bias is now global. McKittrick and Christy (2020) compared tropospheric warming trends in CMIP6 climate models to observed trends from satellites, weather balloons and reanalysis systems. Every model overpredicted the average observed warming trend over 1979-2014 in both Lower- and Mid-Troposphere layers, both globally and in the tropics. In most individual models the bias was statistically significant and on average across models it was highly significant.

Figure 5.4 presents the comparisons with data updated to 2024 (McKittrick and Christy 2025). The recent warm years moved the observed trend up slightly and widened the trend confidence intervals but the overall pattern remains the same: model bias is towards too much warming, in most cases the difference is statistically significant and on average the bias is statistically highly significant. McKittrick and Christy (2020) also showed that the bias is larger in high-ECS models, but even the models with lower average ECS predict too much warming. If future climate models were to realistically represent global tropospheric warming, they would likely be less sensitive than even the low-ECS members of the CMIP6 ensemble.

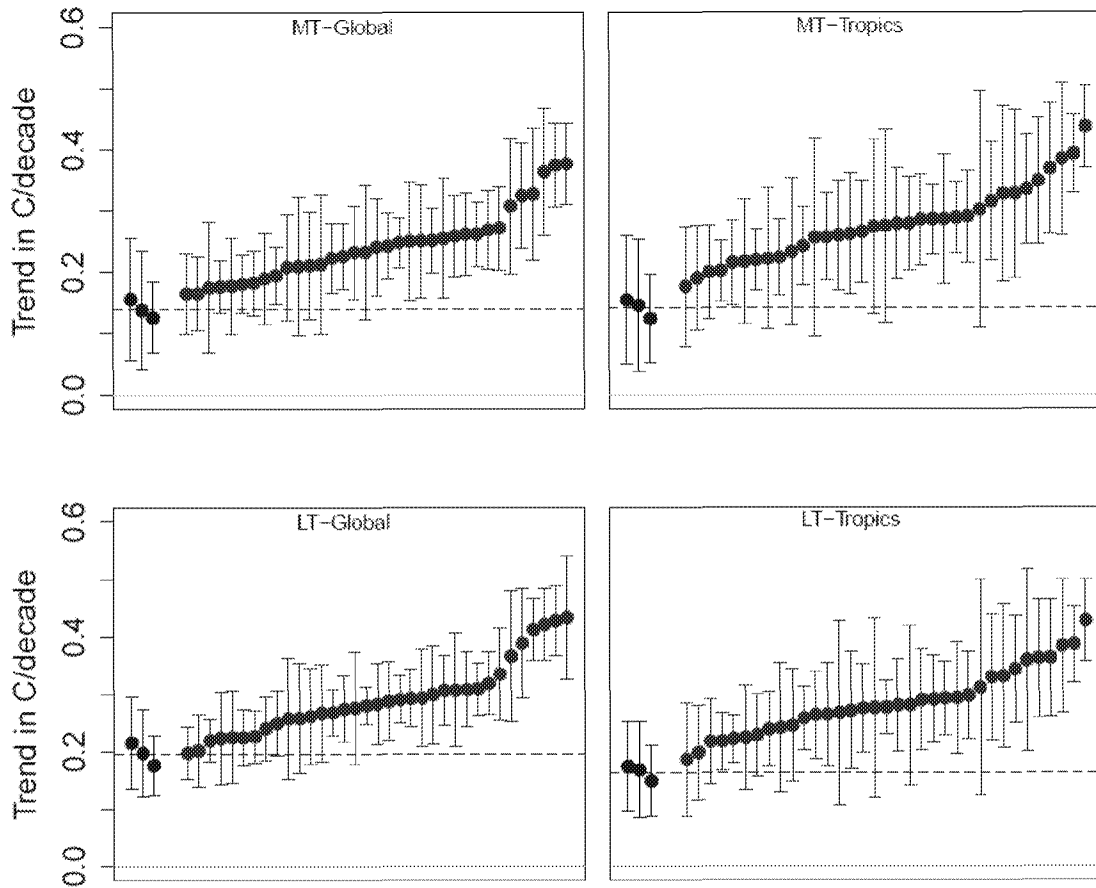


Figure 5.4: Observed versus CMIP6 modeled warming trends ($^{\circ}\text{C}/\text{decade}$ 1979-2024) in the global and tropical lower (LT) and mid-troposphere (MT). Uses methodology of McKittrick and Christy (2020) on data updated from 2014 to 2024. Blue dots: warming trends with 95 percent confidence intervals for 3 data products (radiosondes, reanalysis, and satellites). Blue dashed line: warming trend average for 3 observed series. Red dots: modeled warming trends with 95 percent confidence intervals in 35 models arranged lowest to highest.

As mentioned previously, the IPCC has long acknowledged the model-observation mismatch. For example, AR6 pp. 443-444 offers this on the tropical troposphere (it does not address the global comparison):

Several studies since AR5 have continued to demonstrate an inconsistency between simulated and observed temperature trends in the tropical troposphere, with models simulating more warming than observations (Mitchell *et al.*, 2013, 2020; Santer *et al.*, 2017a, b; McKittrick and Christy, 2018; Po-Chedley *et al.*, 2021)... Over the 1979–2014 period, models are more consistent with observations in the lower troposphere, and least consistent in the upper troposphere around 200 hPa, where biases exceed 0.1°C per decade. Several studies using CMIP6 models suggest that differences in climate sensitivity may be an important factor contributing to the discrepancy between the simulated and observed tropospheric temperature trends (McKittrick and Christy, 2020; Po-Chedley *et al.*, 2021), though it is difficult to deconvolve the influence of climate sensitivity, changes in aerosol forcing and internal variability in contributing to tropospheric warming biases (Po-Chedley *et al.*, 2021). Another study found that the absence of a hypothesized negative tropical cloud feedback could explain half of the upper troposphere warming bias in one model (Mauritsen and Stevens, 2015).

... In summary, studies continue to find that CMIP5 and CMIP6 model simulations warm more than observations in the tropical mid- and upper-troposphere over the 1979–2014 period (Mitchell *et al.*, 2013, 2020; Santer *et al.*, 2017a, b; Suárez-Gutiérrez *et al.*, 2017; McKittrick and Christy, 2018), and that overestimated surface warming is partially responsible (Mitchell *et al.*, 2013; Po-Chedley *et al.*, 2021). Hence, we assess with *medium confidence* that CMIP5 and CMIP6 models continue to overestimate observed warming in the upper tropical troposphere over the 1979–2014 period by at least 0.1°C per decade,

Notably, despite the accumulation of evidence of excess model warming the IPCC assigns only *medium confidence* to the existence of a warming bias.

5.4 Vertical temperature profile mismatch

Another important model-observational discrepancy is the excess amplification with altitude found in climate models. The comparison was in the IPCC AR5 Chapter 10, although only in the online supplement (Figure 10.SM.1) and only in a figure whose formatting obscured the point. Figure 10.SM.1 is not referenced in the main IPCC report nor in any summary so readers would not have been aware of it. Although not apparent at first glance, it shows that the 1979-2010 warming in the lower troposphere is so small as to be consistent with no GHG forcing at all and is inconsistent with the model runs that do have GHG forcing. In Figure 5.6 we adapt IPCC AR5 Figure 10.SM.1 to draw out this critical point.

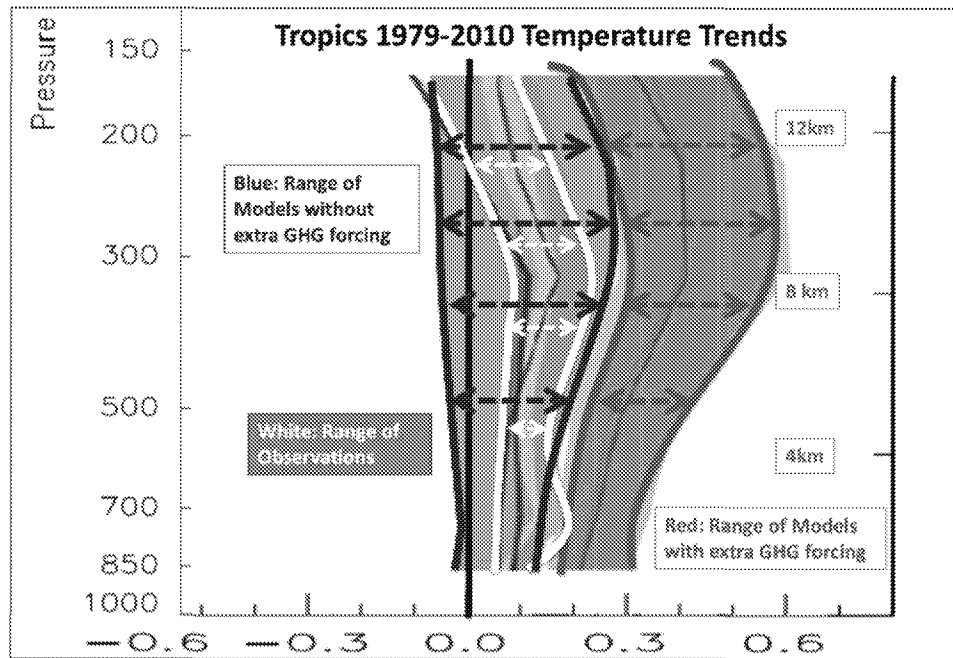


Figure 5.5: Vertical warming pattern for tropics (20S to 20N). Source: Annotated version of IPCC AR5 Figure 10.SM.1

Figure 5.5 compares model and observational temperature trends by altitude between 20S and 20N (the tropics). In this region where the models say the warming should be strongest, the observations (shown here in white) lie within the blue “No CO₂” band and entirely outside the “with CO₂” red envelope. This means that in the entire tropical atmospheric column from the surface to the base of the stratosphere, observed warming trends are so small as to be consistent with the output of models that have no anthropogenic CO₂, and inconsistent with the entire envelope of warming trends generated by models forced with increased CO₂.

A similar comparison is shown in Christy and McNider (2017), an updated version of which (covering 1979-2024) is reproduced as Figure 5.6. Modeled temperature trends exceed observations from the surface through the top of the troposphere, with observed trends below the entire model range at most pressure levels. Also shown in Figure 5.6 is the tropical tropospheric temperature (TTT) average from three satellite data products (NOAA, UAH and RSS) compared to the same layer average from climate models for 1979-2024. Again, the observed trends lie below the entire model range.

The wide range of choices made by modelers to characterize the physical processes in the models (see Box: Climate Modeling in Section 5.1 above) is seen by the large spread of trends in the middle troposphere, ± 40 percent about the median (Figure 5.6). This vividly illustrates the uncertainties in attempts to model (parameterize) a complex system involving turbulence, moist thermodynamics, and energy fluxes over the full range of the tropical atmosphere’s time and space scales.

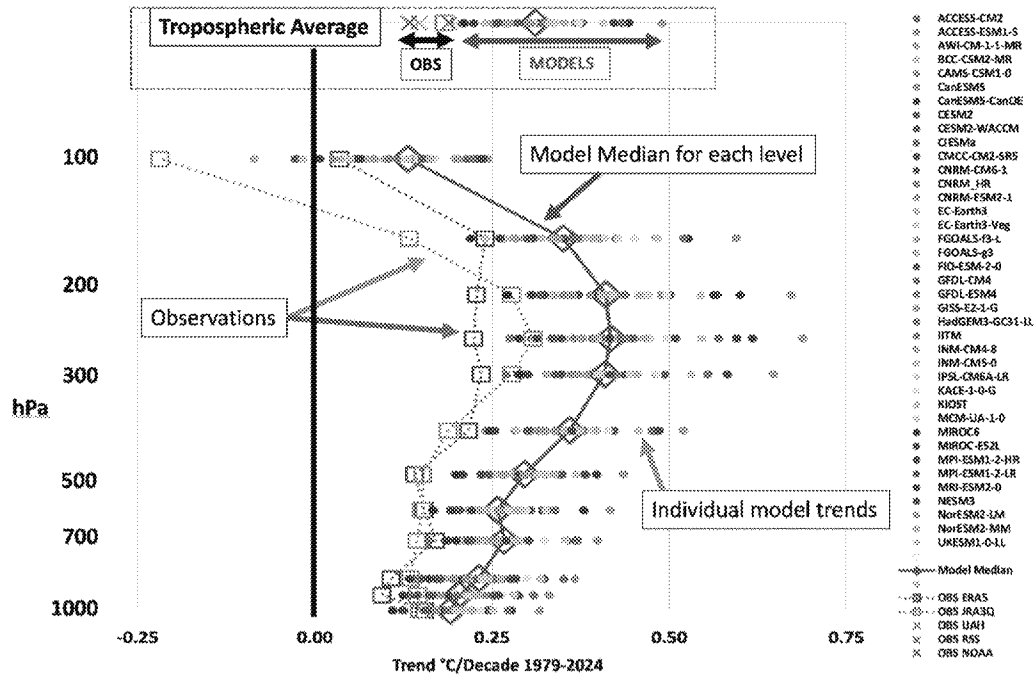


Figure 5.6: Modeled versus observed warming, tropical troposphere. Source: updated from Christy and McNider (2017) including data through 2024 and CMIP6 model outputs. Red line: model average. Green and blue lines: observational series (reanalysis).

This discrepancy has been the source of much controversy, with some arguing that even if there is very little observed warming aloft in the tropics, a “hotspot” still exists in the sense that the warming aloft is greater than at the surface (Santer et al. 2008). But there is good evidence that models also exaggerate the amplification rate. Klotzbach *et al.* (2009), showed that models project greater amplification with altitude than is observed. This result was subsequently confirmed by detailed time series analysis (Vogelsang and Nawaz 2016) which found that the model-observational difference is statistically significant.

The atmosphere’s temperature profile is a case where models are not merely uncertain but also show a common warming bias relative to observations. This suggests that they misrepresent certain fundamental feedback processes.

The IPCC AR6 did not assess this issue.

5.5 Stratospheric cooling

An important element of the expected general “fingerprint” of anthropogenic climate change is simultaneous warming of the troposphere and cooling of the stratosphere. The latter feature is also influenced by ozone depletion and recovery. AR6 acknowledged that cooling had been observed but only until the year 2000. The stratosphere has shown some warming since, contrary to model projections.

AR6 WG1 Ch 2 pp. 327-9 states:

Temperatures averaged through the full lower stratosphere (roughly 10–25 km) have decreased over 1980–2019 in all data products, with the bulk of the decrease prior to 2000. The decrease holds even if the influence of the El Chichon (1982) and Pinatubo (1991) volcanic eruptions on the trend, found by Steiner *et al.* (2020a) to have increased the 1979–2018 cooling trend by 0.06°C per decade, is removed. Most datasets show no significant or only marginally significant trends over 2000–2019, and the results of Philipona *et al.* (2018) show weak increases over 2000–2015 in the very lowermost stratosphere sampled by radiosondes....

It is virtually certain that the lower stratosphere has cooled since the mid-20th century. However, most datasets show that lower stratospheric temperatures have stabilized since the mid-1990s with no significant change over the last 20 years. It is likely that middle and upper stratospheric temperatures have decreased since 1980, but there is low confidence in the magnitude.

The cited source, Philipona *et al.* (2018), in an article entitled “Radiosondes Show That After Decades of Cooling, the Lower Stratosphere Is Now Warming”, stated:

In response to continued greenhouse gas increases and stratospheric ozone depletion, climate models project continued tropospheric warming and stratospheric cooling over the coming decades. Global average satellite observations of lower stratospheric temperatures exhibit no significant trends since the turn of the century. In contrast, an analysis of vertically resolved radiosonde measurements from 60 stations shows an increase of lower stratospheric temperature since the turn of the century at altitudes between 15 and 30 km and over most continents. Trend estimates are somewhat sensitive to homogeneity assessment choices, but all investigated radiosonde data sets suggest a change from late twentieth century cooling to early 21st century warming in the lower stratosphere.

Santer *et al.* (2023) show using updated data that a cooling trend has not re-emerged in the lower stratosphere.

A combination of tropospheric warming and stratospheric cooling is a commonly cited “fingerprint” of anthropogenic climate change. Stratospheric warming since 2000 coincides with continued surface and tropospheric warming, a pattern that is not found in climate model simulations and is not apparently consistent with the anthropogenic fingerprint.

5.6 Snow cover mismatch

Data compiled by the Rutgers University Snow Lab show that Northern Hemisphere winter snow cover is not decreasing (Figure 5.7); if anything, it shows an increasing trend.

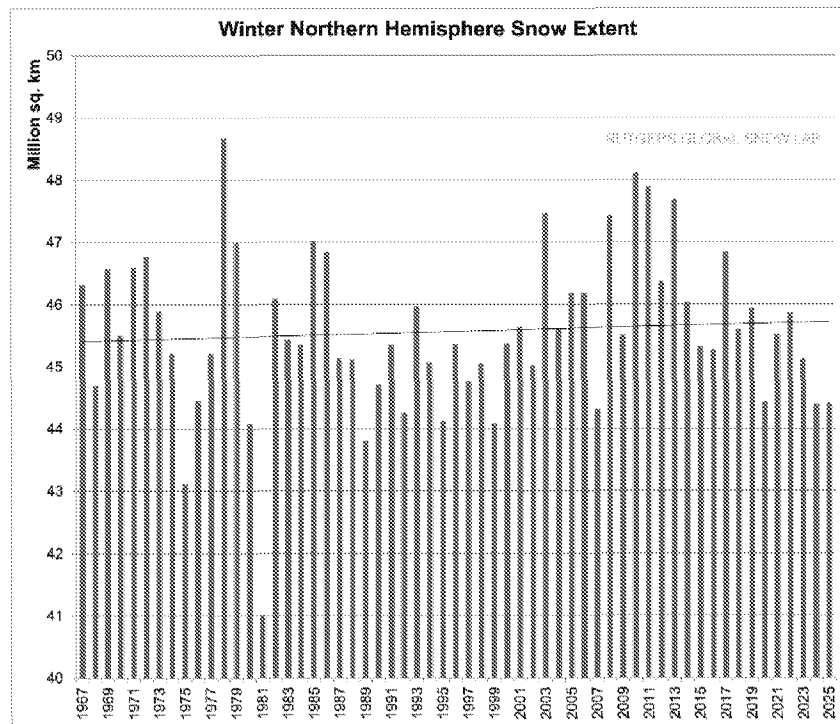


Figure 5.7: Northern Hemisphere Winter Snow extent.

Source: [[HYPERLINK](https://climate.rutgers.edu/snowcover/chart_seasonal.php?ui_set=nhl&ui_season=1)]

"https://climate.rutgers.edu/snowcover/chart_seasonal.php?ui_set=nhl&ui_season=1"]
(accessed May 27, 2025)

Yet models project declining Northern Hemisphere snow cover in a warming climate, as described by Connolly *et al.* (2019).

The climate models were found to poorly explain the observed trends [in Northern Hemisphere snow cover]. While the models suggest snow cover should have steadily decreased for all four seasons, only spring and summer exhibited a long-term decrease, and the pattern of the observed decreases for these seasons was quite different from the modelled predictions. Moreover, the observed trends for autumn and winter suggest a long-term increase, although these trends were not statistically significant.

AR6 largely confines its discussion of changing Northern Hemisphere snow cover extent (SCE) to the Spring season, for which models and observations agree on a downward trend. Regarding Winter changes it remarks as follows (AR6 WGI Ch. 2 p. 344):

Assessment of SCE trends in the NH since 1978 indicates that for the October to February period there is substantial uncertainty in trends with the sign dependent on the observational product. Analysis using the NOAA Climate Data Record shows an increase in October to February SCE (Hernández-Henríquez *et al.*, 2015; Kunkel *et al.*, 2016) while analyses based on satellite borne optical sensors (Hori *et al.*, 2017) or multi-observation products (Mudryk *et al.*, 2020) show a negative trend for all seasons.

AR6 WGI Chapter 9 (p. 1284) points out that the NOAA Climate Data Record showing increased fall and winter SCE is inconsistent with land-based observations and model-based data sets. It notes that using optical satellite imagery to infer SCE in winter is challenging due to cloud cover and decreased solar illumination in winter months. Focusing on the Pacific Coast states (CA, OR and WA) cold season mountain snowfall that melts in spring and summer provides a substantial portion of warm season water resources. A comprehensive reconstruction of snowfall for the main source regions (Cascades and Sierra Nevada Mountains) indicates no significant trends in annual totals since the late 19th century (Christy 2022).

In summary, the up-to-date Rutgers SCE database indicates a mismatch between models and observations. Further work to reconcile conflicting trends in observational data sets is required.

5.7 Hemispheric symmetry of the planetary albedo

The planetary albedo is the fraction of incoming solar radiation reflected by the Earth back to space. It is an important element of the radiative energy balance and influences whether the planet will warm or cool over time. The planetary albedo is typically estimated at around 0.30; variations on the scale of 0.01 correspond to changes in solar forcing of about 3 W/m^2 , an amount larger than current anthropogenic forcing. It has long been noted that models disagree with each other and with observations on the value of the global planetary albedo (Stephens *et al.* 2015).

An intriguing property of the Earth's albedo is that, on average, the Northern Hemisphere (NH) and Southern Hemisphere (SH) have had nearly the same albedo, at least throughout the fifty-year satellite record (Stephens *et al.*, 2015). This symmetry is surprising, because the SH has much more ocean than land. Since ocean is less reflective than land, the NH should have higher albedo. Clouds (which are highly reflective) are more common in the NH and so compensate the surface albedo imbalances of the two hemispheres. Datseris and Stephens (2021) show that this cloud compensation comes from the extra-tropical storm tracks of the SH, which are cloudier than those of the NH. While the mechanism for this hemispheric symmetry is unclear, it likely operates on large temporal and spatial scales.

The hemispheric symmetry of the albedo is a simple gross metric for climate models. Rugenstein and Hakuba (2023) defined that metric as the difference between the NH and SH annual mean albedos, expressed as Wm^{-2} of the reflected sunlight, and compiled it for the CMIP6 climate models, as shown in Figure 5.8. Most of the CMIP6 models do not reproduce the small observed asymmetry (about 0.1 Wm^{-2}) and even disagree as to which hemisphere is more reflective. Moreover, the magnitude of the asymmetry ranges up to 5 Wm^{-2} in some models, twice as large as the current anthropogenic forcing (about 2.5 Wm^{-2}).

The significance of unphysical albedo asymmetries in the climate models is not yet fully known. However, other model studies suggest that interhemispheric changes in albedo can alter poleward heat fluxes, meridional temperature gradients, storminess, and differences in hemispheric ocean heat storage. The discrepancy between models and observations further raises issues regarding cloud feedback processes and so more generally diminishes confidence in model projections of the future climate.

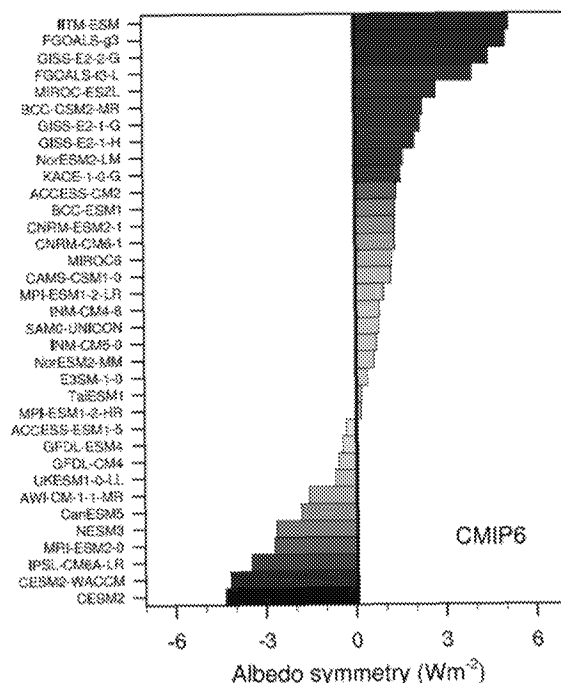


Figure 5.8. Differences in 20-year average reflectivity (albedo) between the Northern and Southern Hemispheres for CMIP6 models used in the most recent IPCC assessment (colored bars). The very small observed difference is indicated by the vertical black line. From Rugenstein and Hakuba (2023).

5.8 U.S. Corn Belt

One of the largest discrepancies between models and observations is in the U.S. Corn Belt, a region of particular importance to global food production. Figure 5.9 shows the warming trends for summertime (June, July, August) for the 12-state Corn Belt (IN, IA, IL, ND, SD, MO, MN, WI, MI, OH, KS, NE) during 1973-2022. All 36 climate models (red) warm far too rapidly compared to observations (blue).

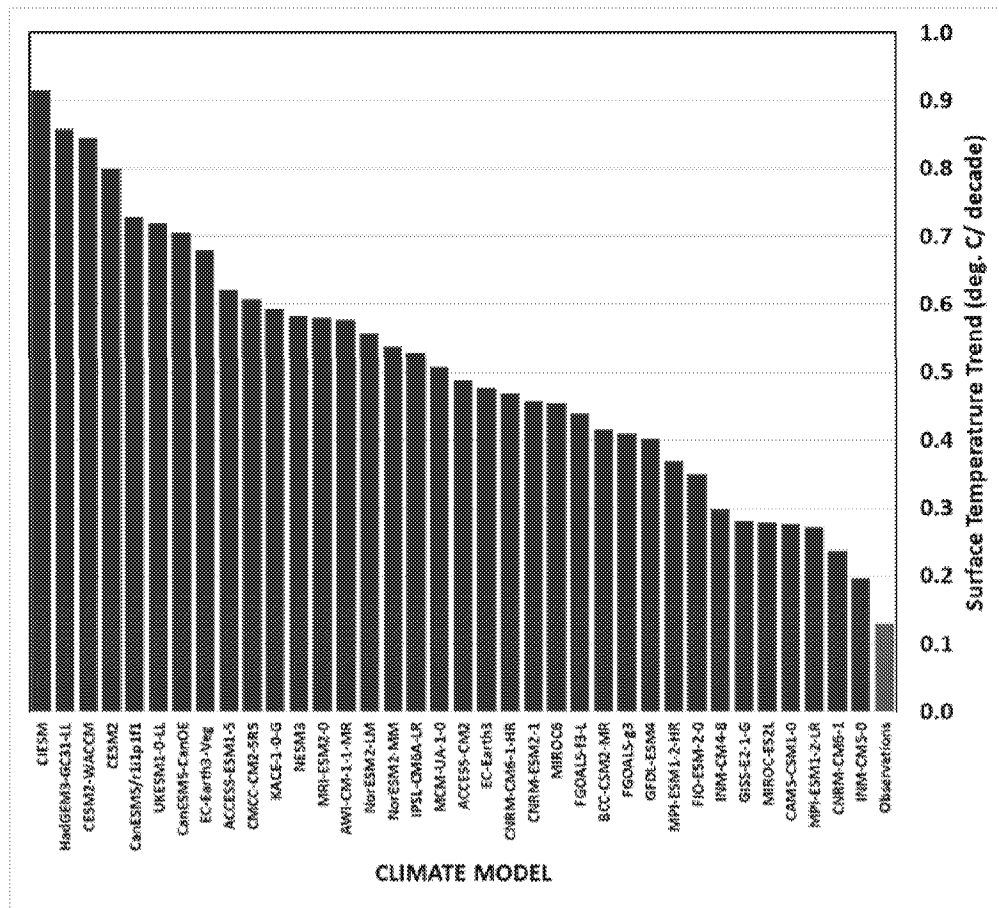


Figure 5.9: Modeled versus observed warming trends in the U.S. Corn Belt, 1973-2022.

As discussed in Chapter 9, the anticipated negative effects of increasing temperatures on U.S. corn yields have not materialized, in contrast to widely publicized studies proclaiming that theoretical future impacts are already being experienced (*e.g.*, Seager *et al.*, 2018).

The IPCC acknowledges limitations in the accuracy of regional climate model outputs. This example shows that users need to assess model projections carefully on a case-by-case basis since local biases might be sufficiently large that the models are simply not fit for purpose. As has recently been noted by two leaders of the modeling community (emphasis added)

... for many key applications that require regional climate model output or for assessing large-scale changes from small scale processes, we believe that **the current generation of models is not fit for purpose**. (Palmer and Stevens 2019)

To summarize:

- Climate models show warming biases in many aspects of their reproduction of the past few decades.
- They produce too much warming at the surface (except in the models with lowest ECS), too much warming in the lower-and mid-troposphere and too much amplification of warming aloft

- They also produce too much stratospheric cooling, too much snow loss, and too much warming in the U.S. Corn Belt.
- The hemispheric albedo difference in individual climate models ranges widely in sign and magnitude compared to observations. The range in W/m^2 is three times larger than the direct anthropogenic forcing of CO_2 .
- The IPCC has acknowledged some of these issues but not others.

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6 EXTREME WEATHER

Chapter Summary

Most types of extreme weather exhibit no statistically significant long-term trends over the available historical record. While there has been an increase in hot days in the U.S. since the 1950s, a point emphasized by AR6, numbers are still low relative to the 1920s and 1930s. Extreme convective storms, hurricanes, tornadoes, floods and droughts exhibit considerable natural variability, but long-term increases are not detected. Some increases in extreme precipitation events can be detected in some regions over short intervals but the trends do not persist over long periods and at the regional scale. Wildfires are not more common in the U.S. than they were in the 1980s. Burned area increased from the 1960s to the early 2000's, however it is low compared to the estimated natural baseline level. U.S. wildfire activity is strongly affected by forest management practices.

6.1 Introduction

High impact weather extremes, usually related to temperature, precipitation and/or high wind, can disrupt infrastructure and therefore endanger human health and wellbeing. The issue is not whether extremes occur. Rather, it is whether there are long-term (decadal scale) changes in the frequency or character of extremes (“detection”), as well as the extent to which such changes and the attendant changes in hazards are caused by anthropogenic emissions of greenhouse gases (“attribution”; e.g., AR6 Seneviratne *et al.* 2021).

Process-based understanding and simple thermodynamic arguments have been invoked to assert that warming is worsening extreme weather events. However, it is naïve to assume that any recent extreme event is caused by human influences on the climate. Climate is about the statistical properties of weather over decades, not single events. Further, there are only about 130 years of reliable observational records that can be analyzed statistically. That brief interval does not begin to contain all the extreme events that the climate system can create on its own. Over geologic time the climate system has generated an (essentially) infinite variety of weather patterns and extremes that humans have never observed and thus are absent from the databases used to determine extreme statistics [see *Perils of short data records* below]. For that reason, attributing an extreme event unprecedented in the record requires assumptions about the magnitude of natural variations.

This chapter is concerned with detection of trends in extreme weather, while Chapter 8 considers causal attribution, with Section 8.4 specifically addressing extreme weather. If no trend is detected, then clearly there is no basis for attribution. But even where a trend is observed, attribution to human-caused warming does not necessarily follow.

This is especially true for precipitation events. The hydrological literature has long noted the presence of long, slow and irregular oscillations in rainfall data (Hurst 1951, Cohn and Lins 2005, Markonis and Koutsoyiannis 2016). The characteristics of these natural patterns require long records to accurately estimate variability. Analysis of records that are short relative to the scale of natural variability will tend to misrepresent trends, therefore overstating the significance of apparent trends and underestimating the likelihood of extreme events (Cohn and Lins 2005).

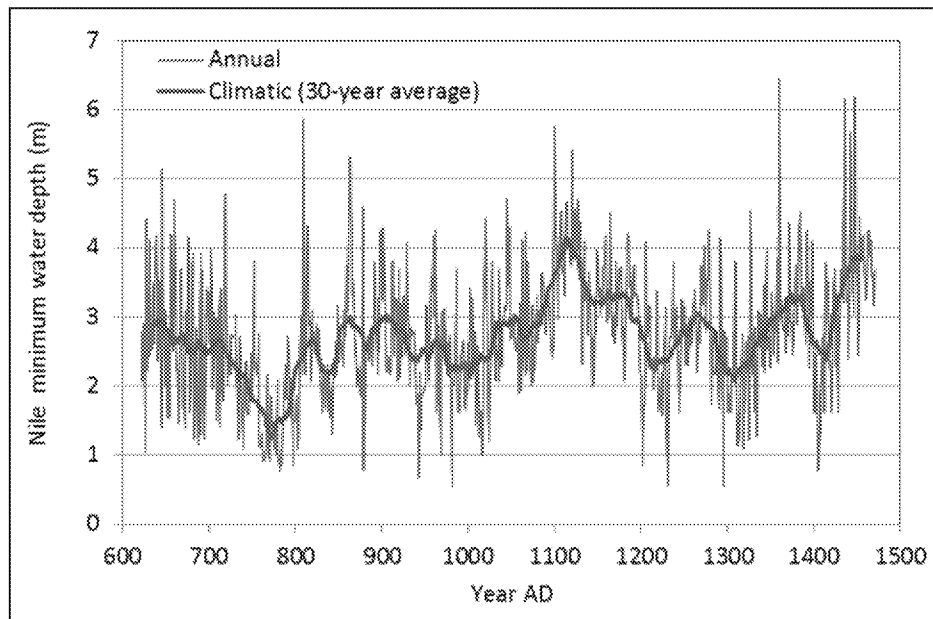


Figure 6.1.1: The annual minimum depth of the Nile River near Cairo over more than 650 years from 622 to 1284 A.D. The data, measured in meters, shows a characteristic pattern of year-to-year fluctuations around longer-term trends. Data from Koutsoyiannis (2013)

A good example of this is the eight-century long record of the annual minimum height of the Nile River observed at Roda Island in Cairo shown in Figure 6.1.1. The Nile River is fed by precipitation over a 4 million square mile drainage basin, an area equal to about one third of CONUS. Since human influences on the global climate were negligible before the 20th century, the century-scale variability of the thirty-year average is entirely natural; Egyptians of the seventh and eight centuries would have been incorrect to assume that the worsening drought during that time was the “new normal.”

With these caveats in mind, we examine the evidence for changes in selected weather and climate extremes. A recurring theme is the wide gap between public perceptions and scientific evidence. It has become routine in media coverage, government and private sector discussions, and even in some academic literature to make generalized assertions that extreme weather of all types is getting worse due to GHGs and “climate change.” Yet expert assessments typically have not drawn such sweeping conclusions and instead have emphasized the difficulty both of identifying specific trends and establishing a causal connection with anthropogenic forcing.

In the sections to follow we provide excerpts from various IPCC and NCA assessment reports denoting the sources as follows:

SREX: The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2012)

AR6: The IPCC Sixth Assessment Report Working Group 1 (2021).

NCA4: The U.S. Climate Science Special Report of the Fourth National Climate Assessment (2017) Volume I.

NCA5: The U.S. Climate Science Special Report of the Fifth National Climate Assessment (2023) Volume I.

In the excerpts, *italics* are in the original whereas **boldface** emphasis has been added.